GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST) OBSERVATORY

ELECTROMAGNETIC INTERFERENCE (EMI) REQUIREMENTS DOCUMENT

APRIL 24, 2002

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

433-RQMT-0005

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(GLAST)
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NASA Goddard Space Flight Center

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GLAST Observatory
Electromagnetic Interference (EMI) Requirements Document

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1 INTRODUCTION

1.1 Scope

This Electromagnetic Interference (EMI) Requirements document defines the overall approach and design criteria to ensure compatible operation of the GLAST Observatory in accordance with the Contract Data Requirements List, 433-CDRL-0002. This document provides the EMI requirements and management organization procedures for the prime contractor, subcontractors and vendors as it relates to EMC control. The document identifies the particular requirements in the design area for bonding, grounding, and shielding to control radiated and conducted emissions and susceptibility to specified EMI/EMC levels.

General Spacecraft and Instrument EMI requirements and traceability are identified in Section 3. The system level (Observatory) EMI requirements are specified in Section 4. Spacecraft component EMI requirements are specified in Section 6 and may reference paragraphs of Section 4. Instrument specific EMI requirements are specified only in Sections 1 through 3 and 5. Spacecraft ground support equipment requirements are specified in Section 7.

1.1.1 GLAST Observatory Description

Please refer to the Spacecraft Performance Specification and the Mission System Specification for the description of the Observatory.

Figure 1. Spacecraft Diagram (Reference Only) TBD

2. APPLICABLE DOCUMENTS

The applicable documents for Observatory EMI are listed in Sections 2.1 and 2.2 below and in Figure 2, EMI Document Tree. The documents in Section 2.3 are reference documents for the program requirements as specified in this requirement document. The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced below and the contents of this specification, the contents of this specification shall take precedence.

2.1 Government Documents

2.1.1 Specifications

Federal

None

Military

EWR 127-1 31 October 1997	Eastern and Western Range Safety Requirements

NASA Documents

433-SPEC-0003 January 2001	GLAST Spacecraft Performance Specification
433-MAR-0003 date (TBD)	GLAST Spacecraft Mission Assurance Requirements
433-MAR-0001 October 2000	LAT Mission Assurance Requirements
433-SRD-0001 September 2000	GLAST Science Requirements Document
GEVS-SE January 1996	General Environmental Verification Specification for STS and ELV, GFSC
JSC-07636 November 1975	Space Shuttle Program Lightning Protection Criteria Document, Rev A, NASA, L.B. Johnson Space Center

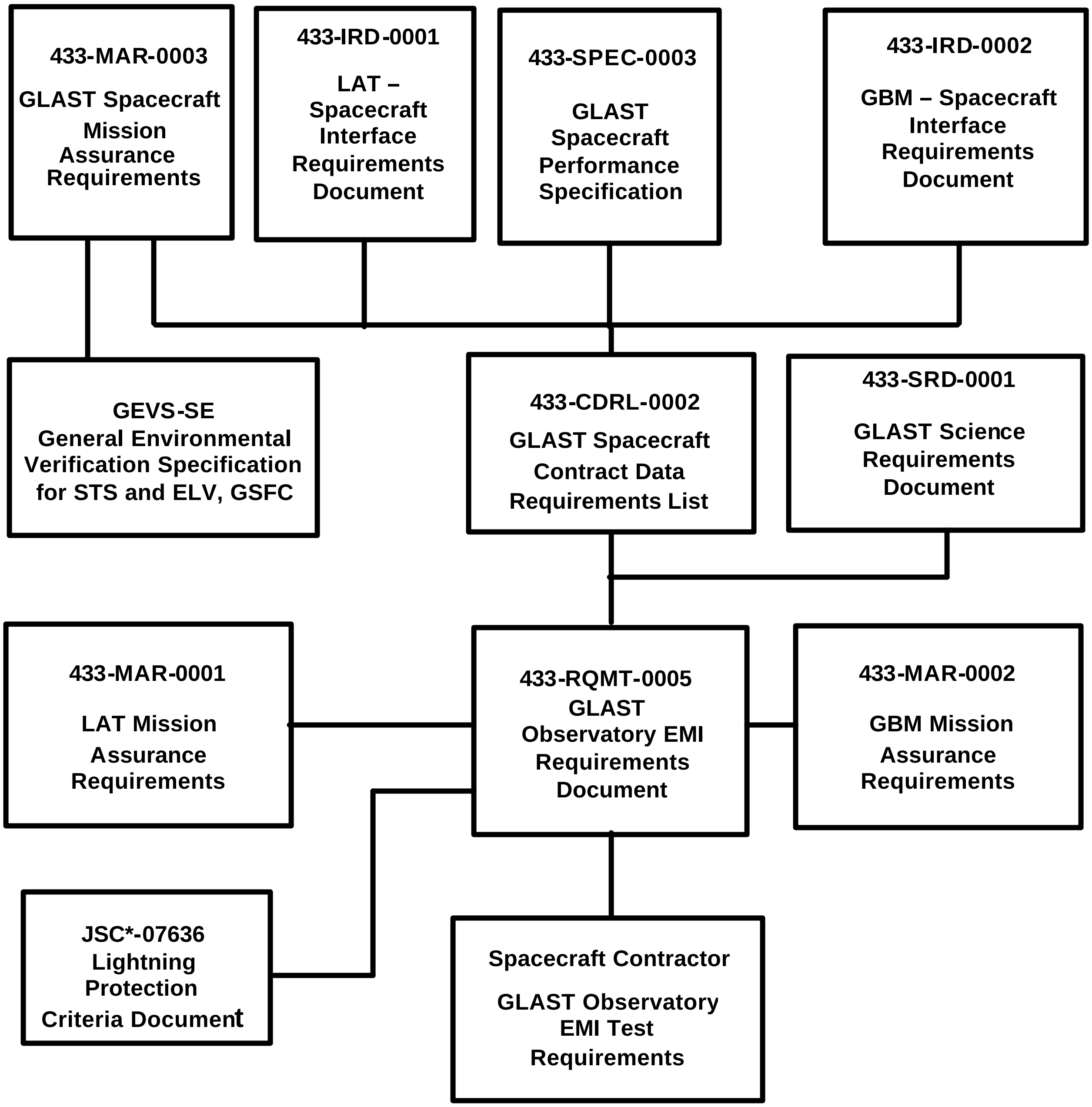


Figure 2. EMI Document Tree

433-CDRL-0002 date (TBD)	GLAST Spacecraft Contract Data Requirements List (CDRL)
433-IRD-0001 January 2001	LAT – Spacecraft Interface Requirements Document (IRD)
433-IRD-0002 January 2001	GBM – Spacecraft Interface Requirements Document (IRD)
433-IRD-0003 date (TBD)	Launch Vehicle Interface Requirements Document (IRD)

2.1.2 Standards

Federal

NASA-STD-8739.4 February 1998	Crimping, Interconnecting Cables, Harness, and Wiring
NASA-STD-8739.3 December 1997	Soldered Electrical Connections

Military

MIL-STD-461E 20 August 1999	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464 18 March 1997	Electromagnetic Environmental Effect Requirements for Systems
MIL-STD-1541A 30 December 1987	EMC Requirements for Space Systems
MIL-STD-1576, Notice 1 4 September 1992	Electro-Explosive Subsystem, Safety Requirements and Test Methods for Space Systems

Other Government Agency

None

2.1.3 Drawings

None

2.1.4 Other Publications

2.1.5 Handbooks

MIL-HDBK-83575 4 June 1998	General Handbook for Space Vehicle Wiring, Harness Design, and Testing

2.2 Non-Government Documents

2.2.1 Specifications

Spacecraft Contractor date (TBD)	GLAST Observatory EMI Test Requirements

2.2.2 Standards

None

2.2.3 Drawings

None

2.2.4 Other Publications

None

2.2.5 Procedures

None

2.3 Reference Standards, Specifications, and Handbooks

MIL-STD-461D 11 January 1993	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-462 11 January 1993	Measurement of Electromagnetic Interference Characteristics
NASA Reference Publication 1008 October 1977	Lightning Protection of Aircraft, Fisher and J. A. Plumer
ARP-1481	Corrosion Control and Electrical Conductivity in Enclosure Design
AFSC-DH-1-4	AFSC Design Handbook, Electromagnetic Compatibility

3 EMI REQUIREMENTS

3.1 EMI Requirements Traceability

Table I shows the traceability of EMI requirements between the GEVS, the GLAST Spacecraft Mission Assurance Requirements and the EMI Requirements Document.

Table I. EMI Requirements Traceability (TBR)

Test	MAR Para.#	GEVS Paragraph #	EMIRD Paragraph #	Type
Conducted Emission Tests				
DC Power Leads	3-2	2.5.2.1.a	5.2, 6.2	CE
DC Power Leads	3-2	2.5.2.1.b	5.2, 6.2	CE
Spikes DC Power	3-2	2.5.2.1.c	5.2, 6.2	CE
Antenna Terminals	3-2	2.5.2.1.e	6.13	CE
Prime Power	3-2		4.2	CE
Radiated Emission Tests				
DC Magnetic Flds/Prop. System	3-2	2.5.4.1, 2.5.4.5	4.7	RE
DC Magnetic Flds/Prop Component	3-2	2.5.4.1, 2.5.4.5	5.7, 6.7	RE
AC Magnetic Field (System)	3-2	2.5.2.2.b	4.1	RE
AC Magnetic Field (Component)	3-2	2.5.2.2.b	5.1, 6.1	RE
Electric Fields (System)	3-2	2.5.2.2.c&d	4.1	RE
Electric Fields (Component)	3-2	2.5.2.2.c&d	5.1, 6.1	RE
Antenna Port Emission Tx Levels	3-2	2.5.2.2.e	4.1, 6.13	RE/EMI
Antenna Port Emission Spurious	3-2	2.5.2.2.f	4.1, 6.13	RE/EMI
Conducted Susceptibility Tests				
Power Line	3-2	2.5.3.1.a	5.4, 6.4	CS
Intermodulation Products	3-2	2.5.3.1.b	6.14	CS
Signal Rejection	3-2	2.5.3.1.c	6.14	CS
Cross Modulation	3-2	2.5.3.1.d	6.14	CS
Power Line Transients	3-2	2.5.3.1.e	5.4, 6.4	CS
Radiated Susceptibility Tests				
Electric Fields and General EMI	3-2	2.5.3.2.a	4.3, 5.3, 6.3	RS/EMI
Perform EMC with Spacecraft Tx	3-2	2.5.3.2.b	4.3, 5.3, 6.3	RS/EMI
Unintentional Electric Field	3-2	2.5.3.2.c	4.3, 5.3, 6.3	RS/EMI
Magnetic Field Susceptibility	3-2	2.5.3.2.d	4.3.2, 5.3.2, 6.3.2	RS

3.2 EMI Requirements Applicability

Table II shows the applicability of GEVS traceable EMI requirements at various levels of assembly and the specific requirement paragraph in the EMI Requirements Document.

Table II. EMI Requirements Applicability (TBR)

Test	EMI RD Top Level Para. #	Level of Assembly				
		Note	OBS		Equip.(6)	INST
Conducted Emission Tests						
DC Power Leads	5.2, 6.2				X	X
Spikes DC Pwr	5.2		X		X	X
Antenna Terminals	5.13, 6.13				X	X
Prime Power	4.2	2	X			
Radiated Emission Tests						
Magnetic Properties (System)	4.1, 4.7	4	X			
Magnetic Properties (Equip/Inst)	5.7, 6.7				X	X
AC Magnetic Field (System)	4.1		X			
AC Magnetic Field (Equip/Inst)	5.1, 6.1				X	X
Electric Fields (System)	4.1		X			
Electric Fields (Equip/Inst)	5.1, 6.1				X	X
Antenna Port Emission (Equip)	6.13	5	X		X	
Conducted Susceptibility Tests						
Power Line	4.4, 5.4, 6.4				X	X
Intermodulation Products	6.13				X	
Signal Rejection	6.13				X	
Cross Modulation	6.13				X	
Power Line Transients	4.4, 5.4, 6.4				X	X
Radiated Susceptibility Tests						
Electric Fields and General EMC	4.3, 5.3, 6.3	3, 4	X		X	X
EMC with Spacecraft Tx	4.3, 5.3, 6.3	3, 4 3, 4	X X		X X	X X
Unintentional Electric Field	4.3, 5.3, 6.3		X		X	X
Magnetic Field Susceptibility	4.3, 5.3, 6.3	2	X		X	X
OBS = Observatory Level **Equip = Equipment Level**	 **INST = Instrument**				**Tx = Transmitters**	

Notes 2 Performed at system and subsystem level only
3 Definition of susceptibility defined in individual test plan per paragraph 4.3
4 System level requirement met by analysis and comparison of system and lower level of assembly test data
5 System level test performed as part of radiated EMC with Spacecraft Transmitters
6 These are the design requirements. Delineation of Qualification and Acceptance Test requirements vs level of assembly is specified in Tables IV and V.

3.2.1 EMI Requirements List

Table III summarizes all of the requirements contained in this EMI Requirements Document.

3.2.2 EMI Requirements Matrix

Table IV tabulates the requirements contained in this EMI Requirements Document (Table III) vs. the GLAST equipment list.

3.3 EMI Requirements for the Launch Environment

3.3.1 Interface EMI Requirements

The Spacecraft and its components that are active during the launch phase shall comply with the requirements in 433-MAR-0003. The applicable Spacecraft operational or vulnerable elements will meet the requirements of EWR 127-1, JSC-07636 revision A, and 433-IRD-0003.

3.3.2 Launch Phase Lightning Threat

[1] The Spacecraft Pyrotechnic circuits shall not exhibit initiation, upset, performance degradation, or failure when subjected to a lightning threat with the characteristics of Figure 3. The figure is derived from the Space Shuttle Lightning Protection Criteria Document (JSC*-07636) for shuttle launched Space Station items.

[2] Lightning threat analysis shall be based upon JSC*-07636.

3.4 EMI Testing

[1] Except where specified, all EMI tests shall be performed per the GLAST Observatory EMI Test Requirements (TBS- Spacecraft Contractor). Qualification testing shall be performed per Table V. The instruments shall meet the requirements of the GLAST Observatory EMI Test Requirements (TBS- Spacecraft Contractor) in their EMI test plans.

[2] The hierarchy of applicable test documents shall be, in descending order, the GLAST Observatory EMI Test Requirements, GEVS-SE, and MIL-STD-461E.

3.5 General Requirement, Electromagnetic Compatibility

The GLAST Spacecraft shall be self-compatible, compatible with its intended electromagnetic environment and meet its EMI requirements.

Table III. EMI Requirements List

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30Hz to 10kHz
CE102	Conducted Emissions, Power Leads, 10kHz to 10MHz
CECM	Conducted Emissions, Common Mode, 30Hz to 50 MHz
CE106	Conducted Susceptibility, Antenna Terminal, 1MHz to 40GHz
CS101	Conducted Susceptibility, Power Leads, 30Hz to 150kHz
CS103	Conducted Susceptibility, Antenna Port, Inter-modulation, 15kHz to 10GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30Hz to 20GHz
CS105	Conducted Susceptibility, Antenna Port, Cross Modulation, 30Hz to 20GHz
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10kHz to 100MHz
RE101	Radiated Emissions, Magnetic Field, 20Hz to 50kHz
RE102	Radiated Emissions, Electric Field, 10kHz to18GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10kHz to 40GHz
RS101	Radiated Susceptibility, Magnetic Field, 20Hz to 50kHz
RS103	Radiated Susceptibility, Electric Field, 2MHz to 40GHz

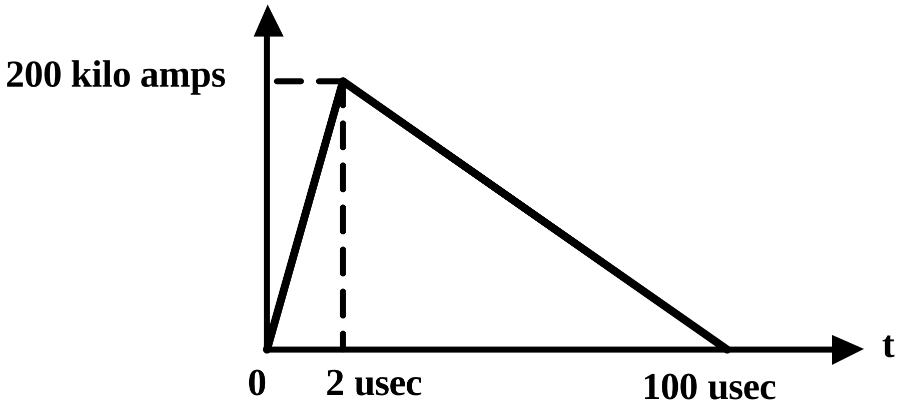
Table IV. EMC Requirements Matrix

CH-01

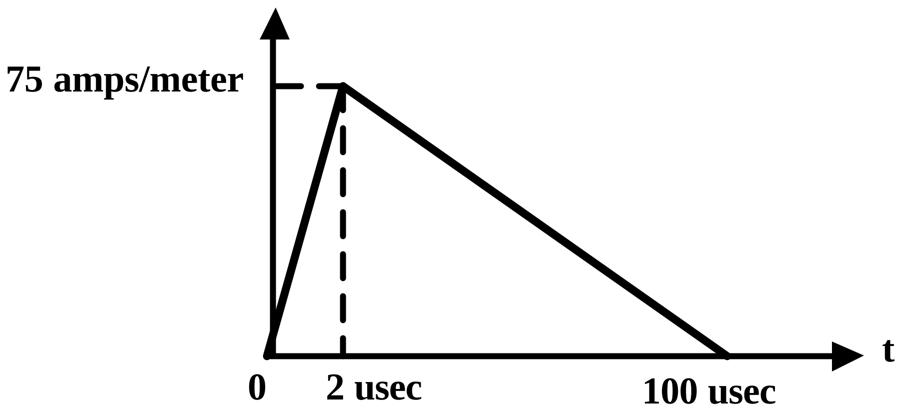
EMC Requirement	Spacecraft	Equipment Modules						
		COMM	**Prop**	GN&C	RWA-EM	Recorder	DAS Panel	EPEM
CE Ripple-Primary Power	**System**							**Test +**
CE Ripple-Secondary Power								
CE01&CE03								
CE Common Mode								
CE06								
RE02 System	Anal/Test							Note (1,2)
RE02 Instrument, S/C Equipt.								
RE04 System	Anal/Test							
RE04 Instrument, S/C Equipt.								Note (1,2)
CS01, CS02, & CS06 System	**Analysis**							
CS01 &CS02 Inst, S/C Equipt.								
CS06 Instrument, S/C Equipt.	**Analysis**							
CS06 Applicable limits(s)=								
CS03,CS04,CS05, Ant Port								
RS01 Instrument, S/C Equipt.								
RS03 Perform								
RS03 On-Orbit								
RS03 Launch	Anal/Test							
RS03 S/C Internal Equip								
RS03 S/C External Equip		Anal	Anal	Anal	Anal	Anal	Anal	Anal
DC Magnetic Env								
Magnetic Properties								
EMI Safety Margin, Superpos.	Analysis							
Bonding Spacecraft System	I&T	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst
Bonding Equip;Instruments	I&T	I&T	I&T	I&T	I&T	I&T	I&T	I&T
Conn. And Shield Bonding		Test +	Test +	Test +	Test +	Test +	Test +	I&T
Grounding, Ref & Isol		Inspct	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct
SRP Grounding	I&T							I&T
Structure Grounding	I&T	I&T	I&T	I&T	I&T	I&T	I&T	I&T
Prime Power Grounding	I&T	I&T	I&T	I&T	I&T	I&T	I&T	I&T
Prime Pwr wiring isol. From Chassis	I&T	Test +	Test +	Test +	Test +	Test +	Test +	I&T
Chassis Bonding to SRP	I&T	I&T	I&T	I&T	I&T	I&T	I&T	I&T
Kinematic Mount Isolation	I&T							
Thermal Blanket Grounding	I&T	I&T	I&T	I&T	I&T	I&T	I&T	
Secondary Pwr. Ref.		Test +	Test +	Test +	Test +	Test +	Test +	Ins/Tst
Signal Interfaces Grounding,		Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst
References & Isolation								
Dedicated Returns		Inspct	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct
Signal Interfaces Grounding,		Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst
References & Isolation		Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst	Ins/Tst
NEA and EED Isolation	I&T							
Differential Drivers		Inspct	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct
Fault Wire Grounding	I&T	Test +	Test +	Test +	Test +	Test +	Test +	I&T
Wiring Design	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct	Inspct

Abbreviations: System=Spacecraft with Instruments;COMM=Communication/ C&DH Equipment Module'
Prop=Propulsion Module;DAS Panel=Direct Access System Equipment Panel; EPS= Electrical Power Subsystem
GN&C= Guidence Navigation and Control; RWA-EM = Reaction Wheel Assembly Equiptment Module
Recorder=Recorder Equipment Module; EPEM= Electrical Power Equipment Module
Test= Qualification Test; Test+= Qualification &Accept. Tests; S,O,P=Unit under test shall Survive, Operate, Perform
I&T= Inspect or test at I&T; Inspct=Inspect; Anal=Analysis
Ins/Tst= Inspect or test as applicable; P.Pwr=Prime Power, Note (1)= EPS equipments are tested together
Note (2)=EMC tests at the Equipment Module level are not required but may be performed for risk reduction

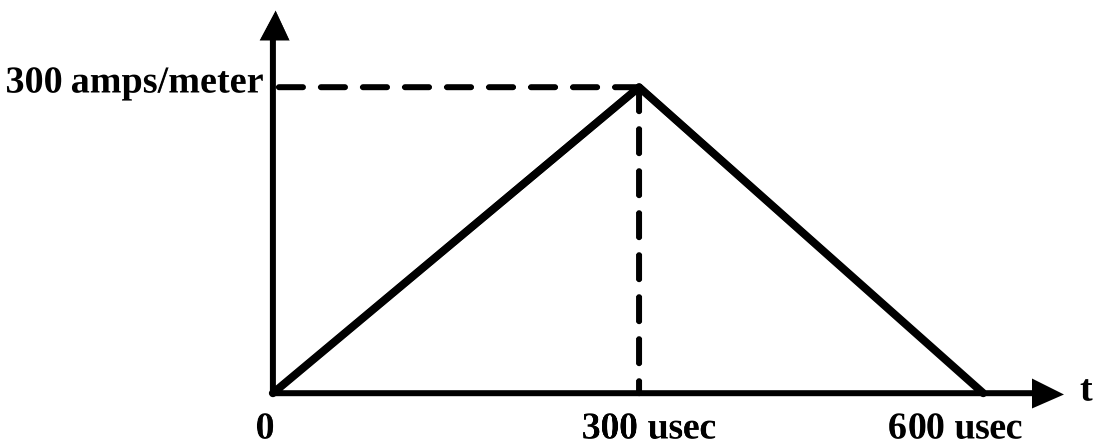
This is an example.



(a) Lightning current



(b) Aperture coupled field, A-component



(c) Diffusion coupled field, B-component

Figure 3. Lightning Threat

Table V. EMI Qualification Testing (TBS)				
Subsystem	**Component**	**A Group Test**	**B Group Test**	**System Test**

4. Observatory/System EMI Requirements

4.1 Radiated Emissions (RE102, RE101)

[1] The Observatory shall not radiate unintentional electric fields in excess of the limits given in Figure 4. Measurement bandwidths above 1 GHz may be modified, if necessary, to achieve sufficient EMI receiver sensitivity.

[2] The Observatory shall not radiate unintentional magnetic field emissions in excess of the limits specified in Figure 5 when measured at 1 meter.

4.2 Prime Power Conducted Emissions (CE101, CE102)

The Observatory prime power line conducted emissions shall be limited to less than the levels in Figures 6a and 6b when measured at the power distribution unit. Test measurement details will be described in separate test documents.

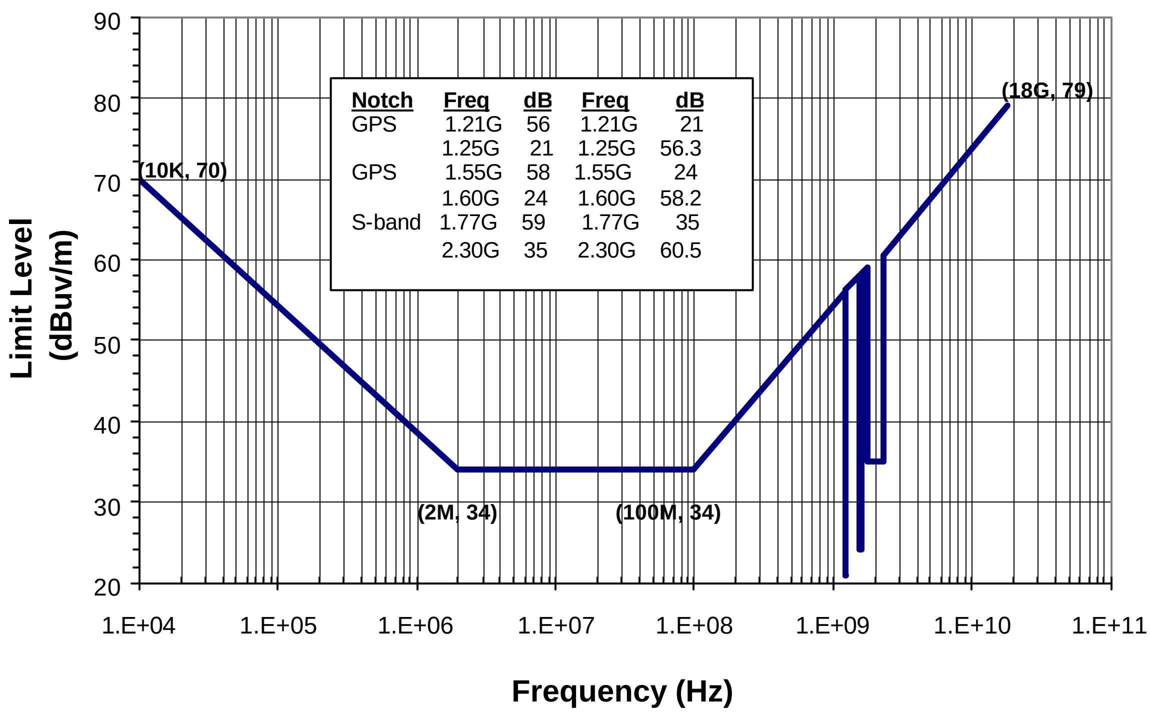


Figure 4. Observatory Radiated Electric Field Emissions Limits (RE102)

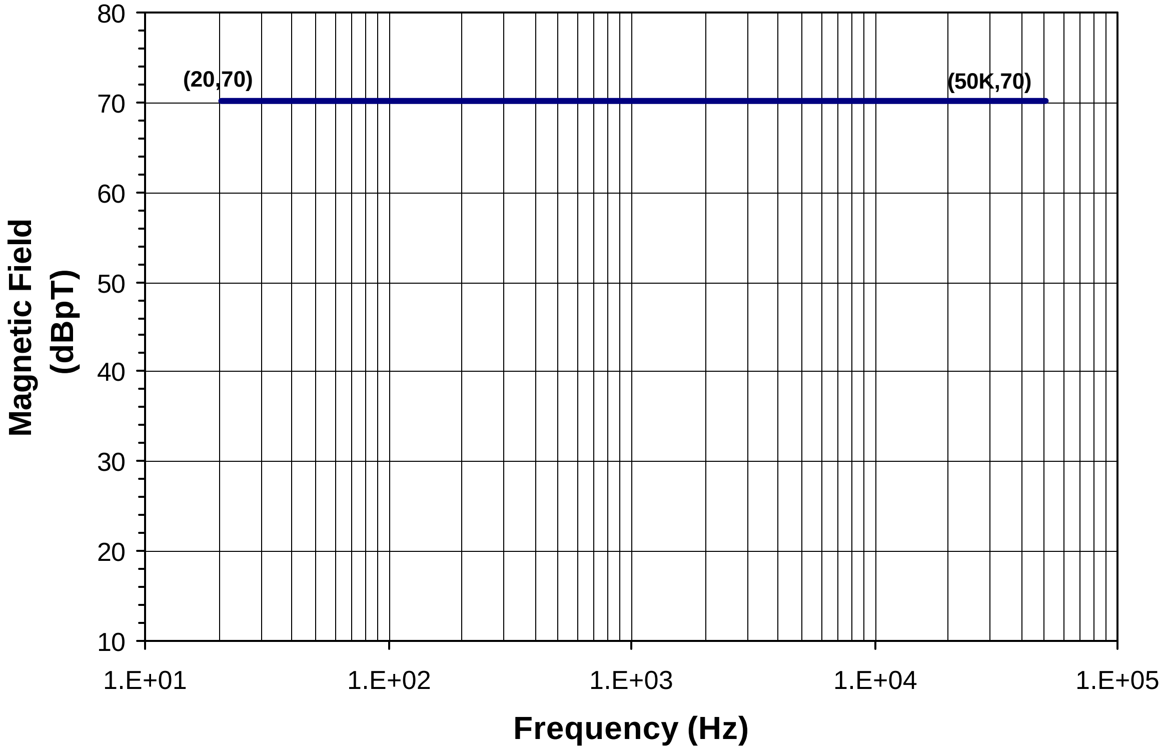


Figure 5. Observatory Radiated Magnetic Field Emissions Limits (RE101)

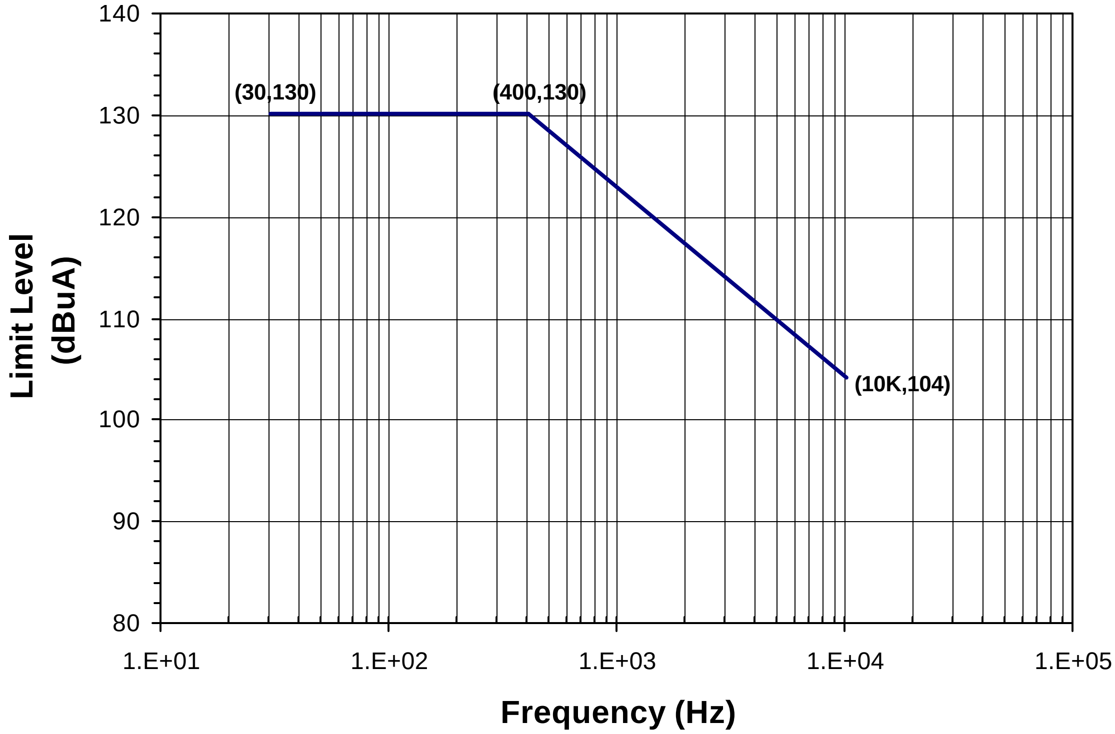


Figure 6a. Observatory Prime Power Conducted Emissions Limits (CE101)

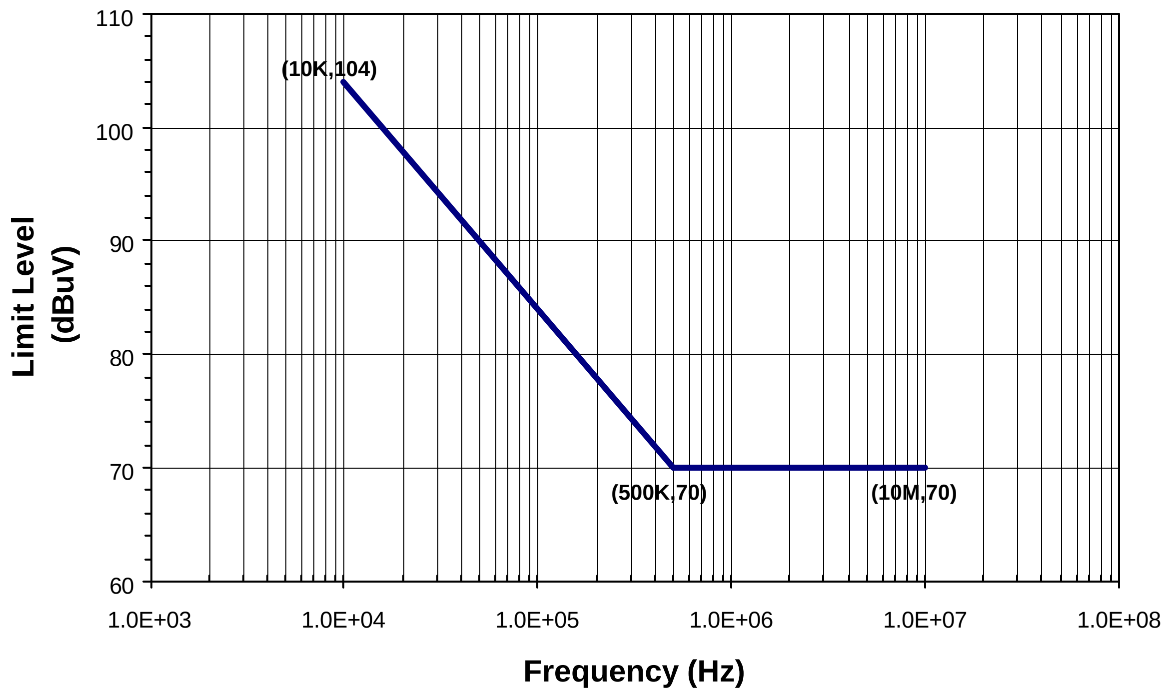


Figure 6b. Observatory Prime Power Conducted Emissions Limits (CE102)

4.3 Radiated Susceptibility and Definition of Susceptibility Criteria

The susceptibility criteria for the Observatory are divided into three categories. These categories are survive, operate and perform and are defined below. The applicability of the applied Environmental levels for Spacecraft equipment is detailed in Section 6.

The susceptibility criteria for instruments are specified in Section 5.3. The susceptibility criteria for Spacecraft equipment are specified in Section 6.3.

a. Survival is defined as the ability to withstand the applied environment without any permanent loss of performance capability. Survival is required for both powered and un-powered states.

b. Operate is defined as the ability to execute all functions except to take scientific data accurately in the applied environment. Operate is the ability to withstand the applied environment without malfunction, loss of capability, change of operation state/mode, memory changes or need for outside intervention. Operate requires that the survival criteria be met.

c. Perform is the ability of the Observatory to meet its specified performance. Perform requires that the Operate criteria be met.

Table VI. Observatory Susceptibility Requirements (TBD)

Test	Spacecraft Equipment		
	Survive	**Operate**	**Perform(5)**
RS103(1)	Y(6,4)	Y(6,4)	Y(6,4)
RS103(2)	Y	Y	Y
RS103(3)	Y	Y	Y
Magnetic Properties(7)	Y	Y	Y

Y = Applicable

(1) Composite of normal checkout, launch vehicle, and launch susceptibility levels (Figure 7)
(2) On-orbit susceptibility levels (Figure 10)
(3) Observatory generated susceptibility levels (Figure 8)
(4) By test or analysis
(5) Definition of susceptibility (i.e., criteria for performance) defined in test plan.
(6) Launch environment and launch environment reduced by equipment module shielding where applicable.
(7) Immunity to Observatory and Earth generated magnetic fields; verified by system self-compatibility

4.3.1 Radiated Susceptibility, Electric Fields (RS103)

[1] The Observatory shall meet the following criteria when subjected to the susceptibility environments specified below.

[2] The Observatory systems that are necessary for launch shall perform when subjected to electric fields over the range of frequencies and at the levels specified in Figure 7.

Figure 7 is the applied maximum levels of the ESMC launch environment sources listed in Table VII and the launch vehicle generated environment.

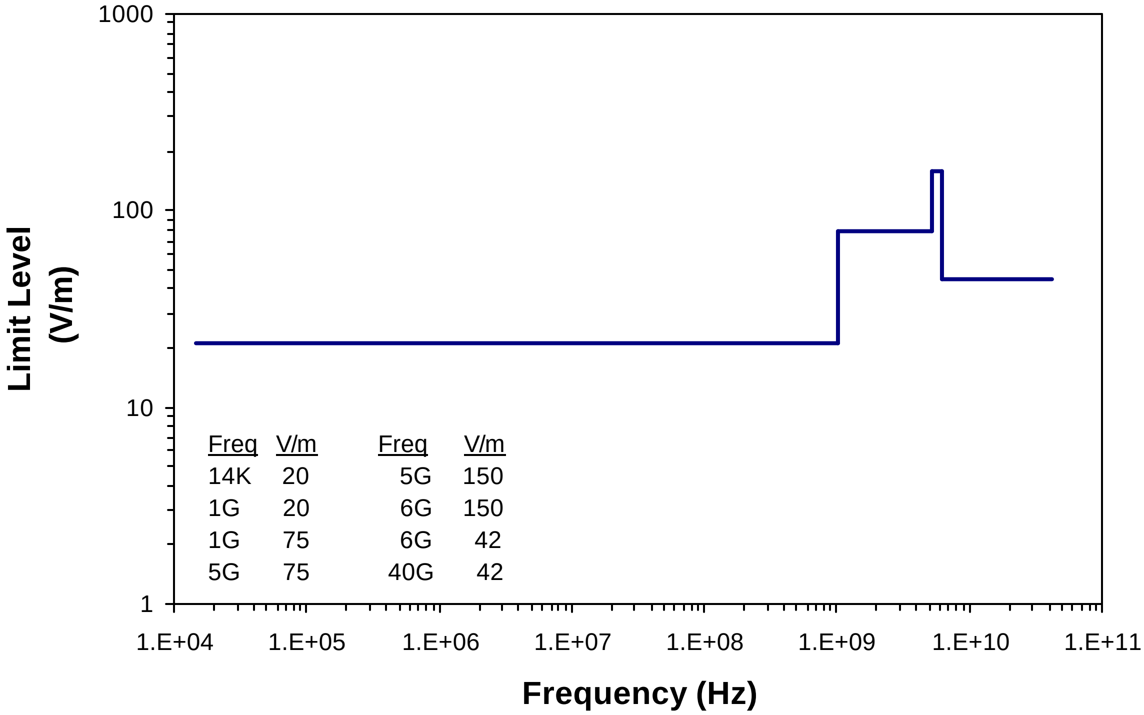


Figure 7. Launch Radiated Susceptibility, Electric Field (RS103) (TBR)

Table VII. High-Level RF Sources for the GLAST Observatory Launch (TBR)								
Equipment	**Low - High Frequency (MHz)**	**Peak Power (W)**	**Min. Power (W)**	**Ant. Gain (dB)**	**Theoretical E-Field Peak (V/m)**	**Measured E-Field Peak (V/m)**	**Avg. Intensity (V/m)**	**Modulation**
Delta II High Level RF Environment								
S-band Telemetry	2241.5		2	2.35	20			
C-band Tracking	5765.0		400	6.00	40			

[3] The Observatory systems shall survive and perform when subjected to electric fields over the range of frequencies and at the levels specified in Figures 7 and 8. The peak transmitter level in Figure 8 for S- and X-bands are the worst-case applied maximum level of Spacecraft sources listed in Table VIII.

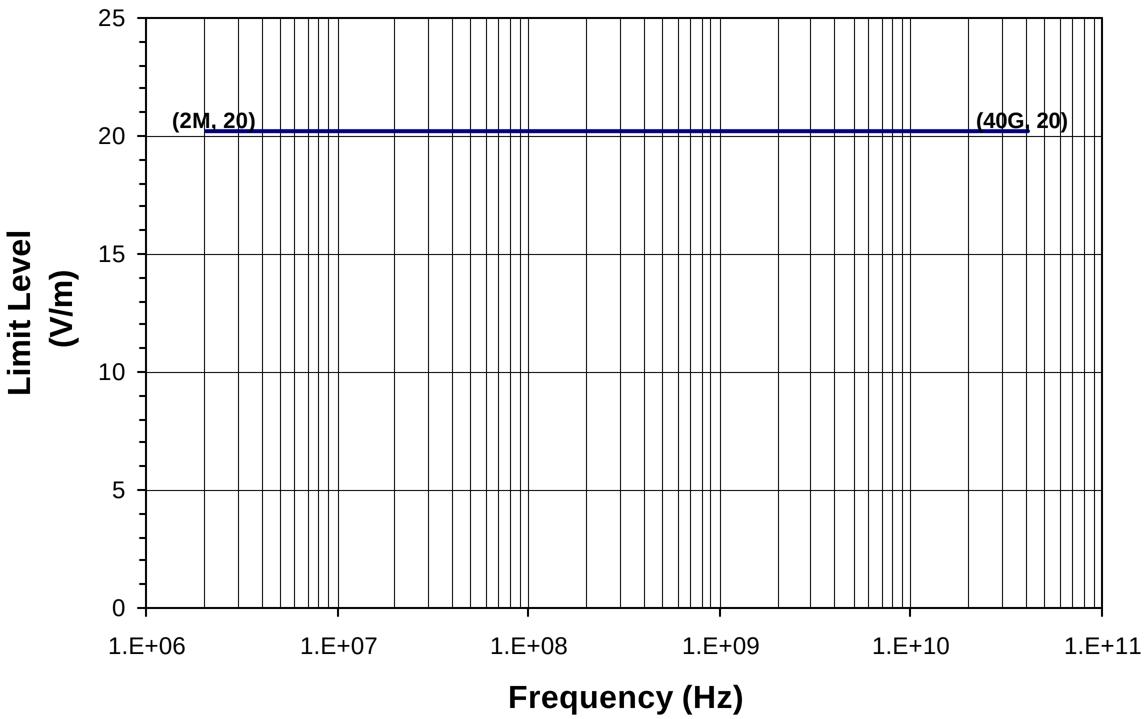


Figure 8. Observatory Generated Radiated Susceptibility, Electric Field (RS103)

Table VIII. Spacecraft-Generated GLAST RF Sources (TBR)					
Transmitter	**Band**	**Center Frequency (GHz)**	**Modulation Type**	**Bandwidth (MHz)**	**Volts/m @ Inst (E_{peak})**
	USB	2.2875	(TBD)	2.112(2)	(TBD)
	USB	2.2875	(TBD)	2.112(2)	(TBD)
	X	7.812	(TBD)	(TBD)(1)	(TBD)
	X	8.212	(TBD)	375(1)	(TBD)

(1) Width of main lobe of the transmitter spectrum (null to null).
(2) TBD

4.3.2 Radiated Susceptibility, Magnetic Fields (RS101, Static)

[1] The Spacecraft EEDs/NEAs shall not be degraded after exposure to the lightning fields specified in paragraph 3.3.2. Equipment necessary for launch shall perform during exposure to the lightning fields specified in paragraph 3.3.2.

[2] The Spacecraft equipment, components, and subsystems shall perform when subjected to the Observatory magnetic field requirement of Figure 9.

[3] All Observatory equipment shall perform in the magnetic fields shown in Figure 9. Figure 9 shows the estimate of worst-case magnetic fields at various locations on the Observatory produced by the magnetic torque rods.

[4] The Spacecraft equipment critical and necessary for launch shall perform during exposure to a 1.5 Gauss (150 uT) Static Magnetic field.

4.4 Conducted Susceptibility (CS101, CS116)

Observatory level conducted susceptibility will be verified by compiling the component level test data for CS101, and CS116 to ensure that the Observatory achieves Electromagnetic Interference Safety Margin (EMISM).

4.5 Not Used

4.6 Deployment EED/NEA Design

The Observatory design shall provide protection from premature deployment of electro-explosive devices (EEDs) and non-explosive actuators (NEA) in accordance with MIL-STD-1576.

4.7 Equipment Magnetic Properties

Observatory equipment static dipole moment shall not exceed 0.3 Am^2 initially and shall not exceed 0.3 Am^2 after torque rod activity. Torquer rods shall be designed to limit residual static dipole moment to 5 Am^2.

4.8 Electromagnetic Interference Safety Margin

The Electromagnetic Interference Safety Margin (EMISM) for safety critical circuits (such as NEAs and EEDs) shall be 20 dB, verified by analysis or test. EMISM for other EMC critical circuits shall be 6 dB, verified by comparison of emissions and susceptibility test data.

Figure 9. Observatory Torquer Rod Magnetic Fields (TBS)

Figure 10. Not Used

Table IX. Not Used

4.9 Superposition

The radiated and conducted susceptibility requirements will be superimposed on the system critical circuit under investigation to establish the EMISM. This requirement shall be verified by analysis of equipment EMI test data.

4.10 Bonding

[1] All metal components and electrical equipment shall be bonded to the Structure Grounding System (SGS).

[2] The Observatory equipment and system electrical ground shall be bonded together so that each metal-to-metal joint is ≤2.5 mΩ DC resistance between elements. Spacecraft metallic structural elements shall be bonded with less than 2.5 mΩ between joints. Spacecraft mechanical structures that are not part of the SGS shall be bonded together so that DC resistance is less than 10 Ω between joints.

[3] Direct bonding is preferred but movable metal-to-metal joints may use bonding straps providing ≤2.5 mΩ DC resistance and ≤100 nH inductance. Equipment shall be bonded to the SGS with redundant bonding straps. Each strap shall provide a bond of less than 2.5 mΩ and 100 nH. The straps shall not restrict equipment replacement.

[4] Thermal blankets shall be bonded to structure with less than 1.0 Ω DC resistance and ≤250 nH inductance (measured after installation). Each blanket shall be grounded by a minimum of two grounding tabs. All metalized layers of thermal blankets shall be bonded together with less than 3.0 Ω across all layers when measured close to, but not on, the grounding tabs. The maximum resistance between grounding tabs shall be 3.0 Ω (measured prior to installation).

[5] The Bonding surfaces will use conductive corrosion protection such as alodine for aluminum or DOW 19 for magnesium.

4.10.1 Connector and Shield Bonding

[1] Multipin connectors that utilize coaxial or triaxial contacts shall bond the overall shield contact to the interface connectors' shell with ≤ 10 mΩ resistance.

[2] The outer shield of all cables shall be 360 degrees bonded to the interface connector shell.

[3] The outer shield of all coaxial cables shall be bonded to the interfacing equipment cases with ≤2.5 mΩ resistance and ≤50 nH inductance.

[4] The outer shield of all twinaxial data bus cables shall be bonded to the interfacing equipment cases with ≤2.5 mΩ resistance and ≤50 nH inductance

[5] The case/outer shields of all equipment that connect to the Spacecraft harnesses shall have sufficient shielding to maintain the overall shielding performance of the interfacing cables.

[6] The case/outer shield described above shall be bonded to the SGS (directly or via local ground planes) with each bond contributing ≤2.5 mΩ resistance and ≤50 nH inductance.

[7] All connectors shall provide positive bonding mechanisms between mating connector halves and shall have conductive finishes.

[8] All connectors shall be 360 degree bonded to equipment case. EMI gaskets shall be used where necessary. Each electrical bond shall be ≤2.5 mΩ resistance.

4.11 Grounding, References, and Isolation

The GLAST Observatory shall conform to the system-grounding concept in Figure 11.

4.11.1 Structure Grounding System

[1] The Structure Grounding System (SGS) primary structure shall have less than 2.4 mH inductance and 0.1 Ω resistance end to end.

[2] Structure members with conductive composite fibers shall be bonded to the Structure Grounding System with less than 1 kΩ.

[3] The prime power bus shall be single point referenced (grounded) with less than 2.5 mΩ DC resistance to the Structure Grounding System at the Single Point Ground (SPG). The prime power bus shall not use chassis or the SGS as power return.

[4] The prime power bus wiring shall be DC isolated from structure by at least 1 MΩ when the SGS is disconnected from the SPG.

[5] Each component, equipment case, and/or chassis shall be bonded to the Structure Grounding System via a direct connection, bond strap or local ground plane per paragraph 4.10.

4.11.2 Kinematic Mount Isolation

Kinematic mounts used for instrument mounting plates or for direct mounting shall provide greater than 10 kΩ DC isolation.

4.11.3 Thermal Blanket Grounding

[1] All metalized layers of thermal blankets shall be grounded to the Structure Grounding System either by direct connection or by bonding to a local chassis or ground plane per Paragraph 4.10.

[2] Closeout blankets between instruments on separate ground islands shall not be grounded such that the ground island concept is violated (i.e., the blankets shall not be grounded to both islands).

4.11.4 Secondary Power Referencing

[1] Each secondary power return conductor, (except when Isolated secondary power is used), shall be grounded to chassis locally thereby providing a DC reference path to the Structure Grounding System. Isolated secondary power is defined as power that is not used to power "Spacecraft to Spacecraft" interface circuits and power that is totally consumed internally.

[2] Isolated secondary circuits may use an internal single point ground system when necessary and when justified through appropriate analysis.

Figure 11. Observatory Grounding Concept (TBS)

4.11.5 Signal Interfaces Grounding, References, and Isolation

[1] The signal grounding between equipment, mounting plates, or system elements will conform to the concept in Figures 12 and 13.

[2] All differential interface signals between equipment shall use a dedicated return conductor (twisted pair) with returns isolated from chassis. The differential interface receiver circuit shall provide 3 kΩ minimum isolation from chassis ground.

[3] RF signal circuits shall utilize coaxial circuit connections and shall be designed so as to minimize the effect of low frequency currents on the outer conductor.

[4] EEDs/NEAs and other safety critical circuits shall have return conductors isolated from chassis by 2 MΩ minimum when bleeder resistors are disconnected.

[5] Equipment shall bond all data bus cable shields to chassis at the Spacecraft Interface. Data bus cable shields shall be bonded to chassis at both ends. Cable shields may be bonded to the Structure Grounding System or chassis at 1 to 3 meter spacing if necessary.

[6] Except for high-speed digital signals all interface signals with fundamental or rise time frequency components greater than 4 MHz shall require the use of coaxial cable.

[7] High-speed digital signal circuits shall be designed to maximize the use of differential drivers and receivers that provide a return that is isolated from chassis.

[8] Passive bi-level and passive analog telemetry sensors shall be isolated from chassis by ≥100 kΩ.

4.12 Wiring Design

[1] The Spacecraft wiring shall be designed in accordance with NASA-STD-8739.3, NASA-STD-8739.4, and Table X.

[2] The Spacecraft design shall provide wire segregation, routing, shielding and shield termination. A 30 mm separation distance between bundled cables is suggested to reduce mutual coupling between shield currents. The LAT and GBM IRDs should be used as a reference for definitions of signal types.

Figure 12. Secondary Electronics Grounding and Data Interface Concept (TBS)

Figure 13. Interface Signal Grounding (TBS)

Table X. Wire Design Requirements (TBR)

Group Designation	Spacecraft Signal Type	Wire Type	Minimum Shielding	Shield Termination
Ia	28 VDC Power	Twisted conductor	OBS	360° @ Backshell
Ib	Secondary Power	Twisted conductor	OBS	360° @ Backshell
IIIa	Analog TLM, Active	Twisted Pair	OBS	360° @ Backshell
IIIb	Analog TLM, Passive	Twisted Pair*	OBS	360° @ Backshell
Ic	Relay Drive Commands	TC (1 Rtn/8 leads with > 2 rtn's /connector)	OBS	360° @ Backshell
Ic	Logic Level Commands	Twisted Pair	OBS	360° @ Backshell
IIIc	Bi-level TLM, Passive	Twisted Pair*	OBS	360° @ Backshell
IIb	Bi-level TLM, Active	Twisted Pair	OBS	360° @ Backshell
Vc	Time Mark and Freq. Bus	Twinax, Similar to Gore CXN2207	2S	360° @ Triaxial Conn.
Vb	Command and TLM Bus	Twinax, Raychem 7724C8664	3S	360° @ Triaxial Conn.
Vb	Science Data (Low Rate)	Twinax, Raychem 7724C8664	3S	360° @ Triaxial Conn.
IIId	Science Data (High Rate)	Dual Gore G2 Coax	2S Foil/Braid	360° @ SMA Conn.
Va	RF/uWave	Coax/waveguide	2S Foil/Braid	360° @ SMA Conn.
IV	EED (Pyro)	1STP	Wrap bundle	360° @ Backshell

Notes:

OBS = Overall bundle shield; **TC** = Twisted conductor **Coax** = Coaxial cable;
Twinax = Controlled impedance twisted shielded pair; **1S** = Single shield; **2S** = Double shield;
3S = Triple shield; **TLM** = Telemetry; * = May be shielded based on location;
Conn. = Connector

Group designations defined in MIL-W-83575A.

5 INSTRUMENT EMI REQUIREMENTS

5.1 Radiated Emissions (RE102, RE101)

[1] Instruments shall limit unintentional electric field emissions (RE102) to levels less than the limits specified in Figure 14. Instruments consisting of more than one stand-alone component shall meet the levels of Figure 14 for each component. Measurement bandwidths above 1 GHz may be modified, if necessary, to achieve sufficient EMI receiver sensitivity.

[2] Instruments shall limit unintentional magnetic field emissions (RE101) to levels less than the limits specified in Figure 15 when measured at a distance of 1 meter from the instrument enclosure.

5.2 Conducted Emissions (CE102, CECM)

[1] Instruments shall limit prime power conducted emissions to levels less than the limits specified in Figure 16.

[2] Instruments shall limit prime power common mode conducted emissions to levels less than the limits specified in Figure 17, and 100 mV peak-to-peak (TBR) in the time domain.

[3] Instruments shall limit repetitive spikes to less than the limits specified in Figure 16 and Figure 17.

5.3 Radiated Susceptibility and Definition of Susceptibility Criteria

The susceptibility criteria for instruments are divided into three categories. These categories are survive, operate and perform and are defined as follows:

a. Survive is defined as the ability to withstand the applied environment without any permanent loss of performance capability. Survival is required for both powered and unpowered states.

b. Operate is defined as the ability to withstand the applied environment without malfunction, loss of capability, change of operation state/mode, memory changes or need for outside intervention. Operate is the ability of an instrument to execute all ancillary and housekeeping tasks including self test but does not include the ability to take scientific data.

c. Perform is defined as the ability to execute its science mission or to meet its specified performance. Perform requires that the Operate criteria be met.

The applicability of the above susceptibility criteria verses the applied environmental levels for the instrument is detailed in Table XI.

5.3.1 Radiated Susceptibility, Electric Fields (RS103)

[1] Instruments shall survive exposure to the radiated susceptibility environments specified in Figure 18.

[2] Instruments shall perform when subjected to the radiated susceptibility environment specified in Figure 19.

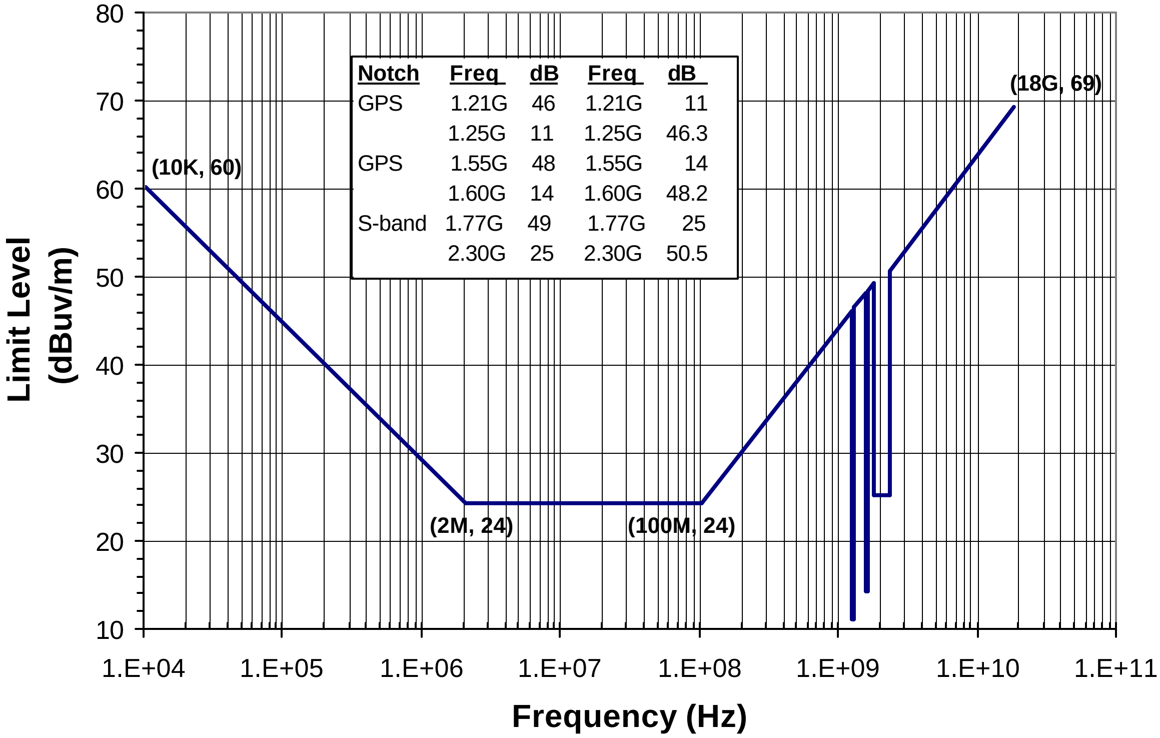


Figure 14. Instrument Radiated Electric Field Emissions Limits (RE102)

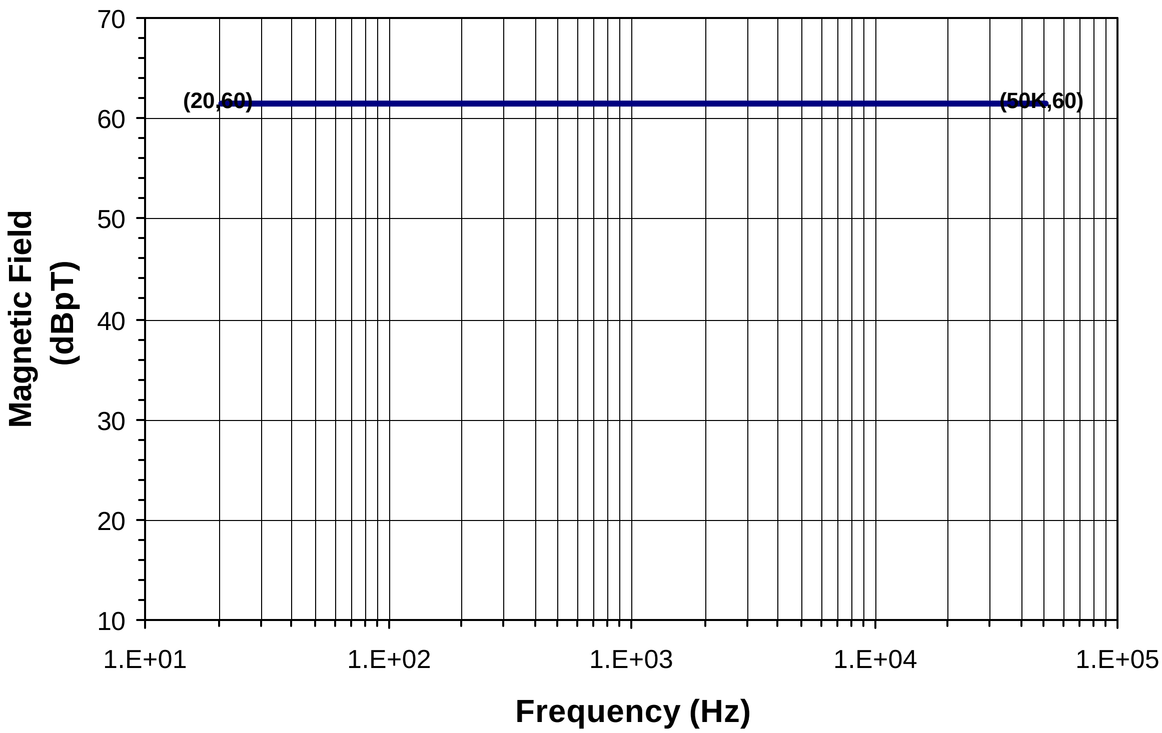


Figure 15. Instrument Radiated Magnetic Field Emissions Limit (RE101)

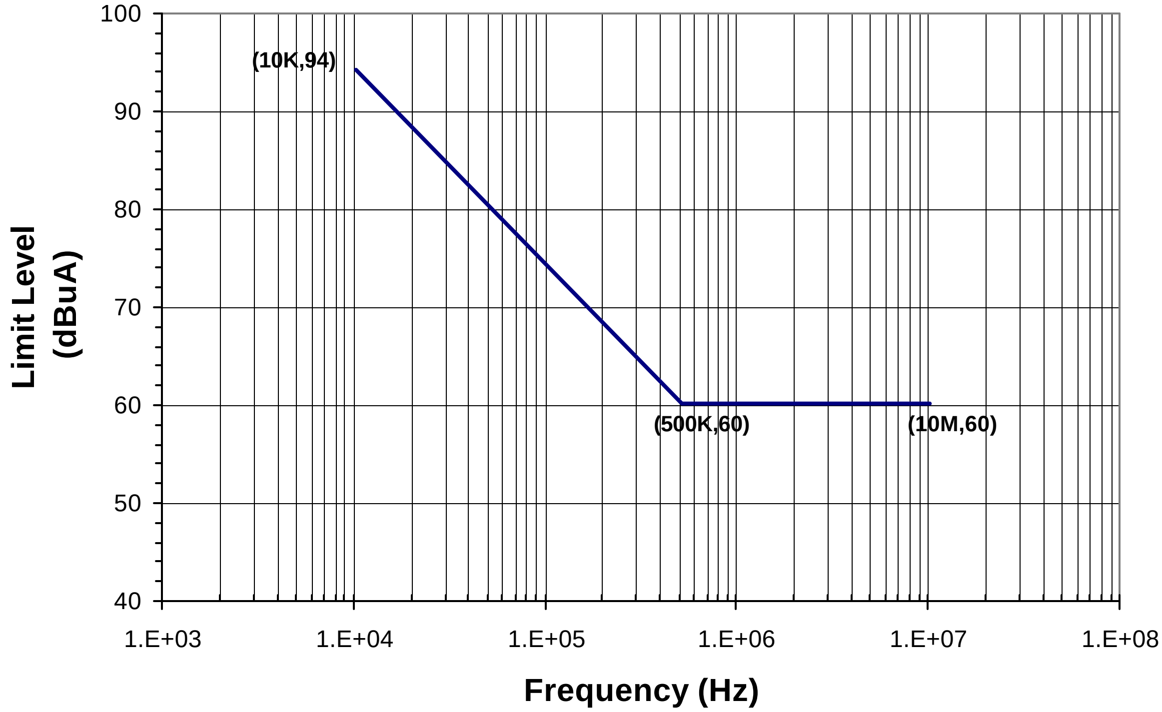


Figure 16. Instrument Conducted Emissions Limits (CE102)

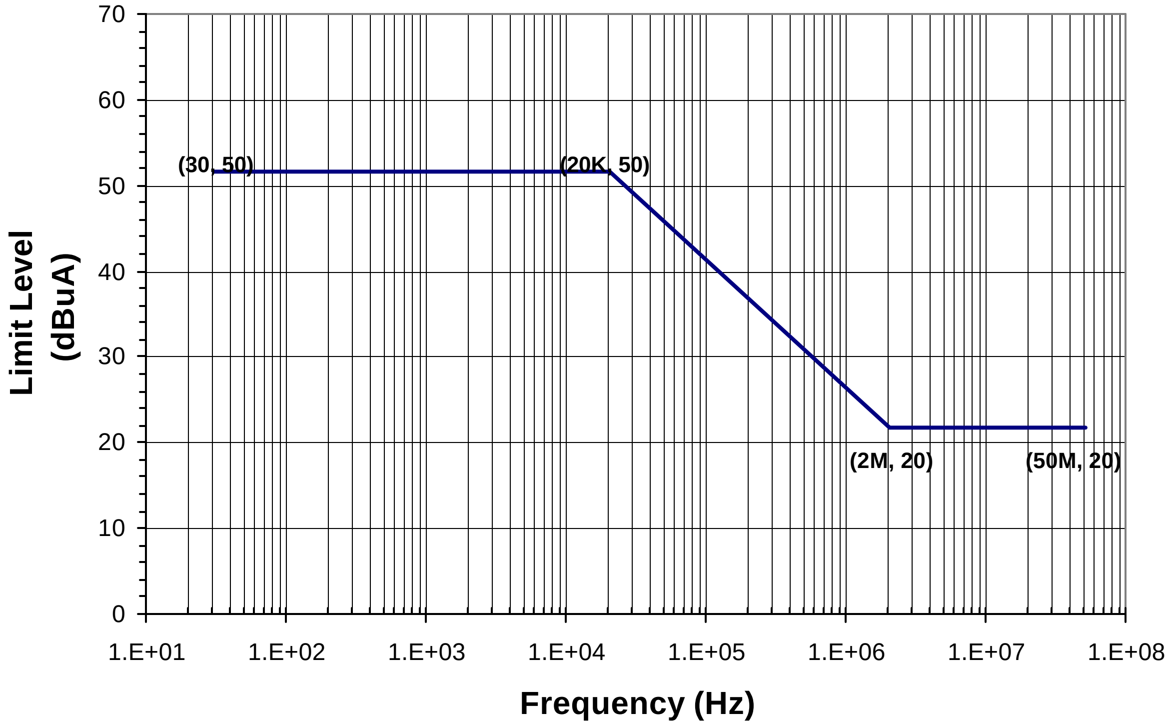


Figure 17. Instrument Common Mode Conducted Emissions Limits (CECM)

Table XI. Instrument Susceptibility Requirements			
Test	**Instruments**		
	Survive	**Operate**	**Perform**[5]
CS101	-	-	Y
CS106	Y	Y	Y
RS101	-	-	Y
RS103[1]	Y[4]	N[4]	N
RS103[2]	Y[4]	Y[4]	D[4]
RS103[3]	Y	Y	Y
Magnetic Properties[6][7]	Y	Y	Y
Y = Applicable; N = Not Applicable; D = Degraded Sensitivity, Test Plan specifies limits			

(1) Composite of normal checkout, launch vehicle, and launch susceptibility levels (Figure 18)
(2) On-orbit susceptibility levels from Joint Spectrum Center (JSC) data for the GLAST orbit (Figure 22)
(3) On-orbit Spacecraft generated susceptibility levels (Figure 19)
(4) By analysis or test
(5) Definition of susceptibility (i.e., criteria for performance) defined in test plan.
(6) Immunity to Spacecraft and Earth generated magnetic fields
(7) Box level test

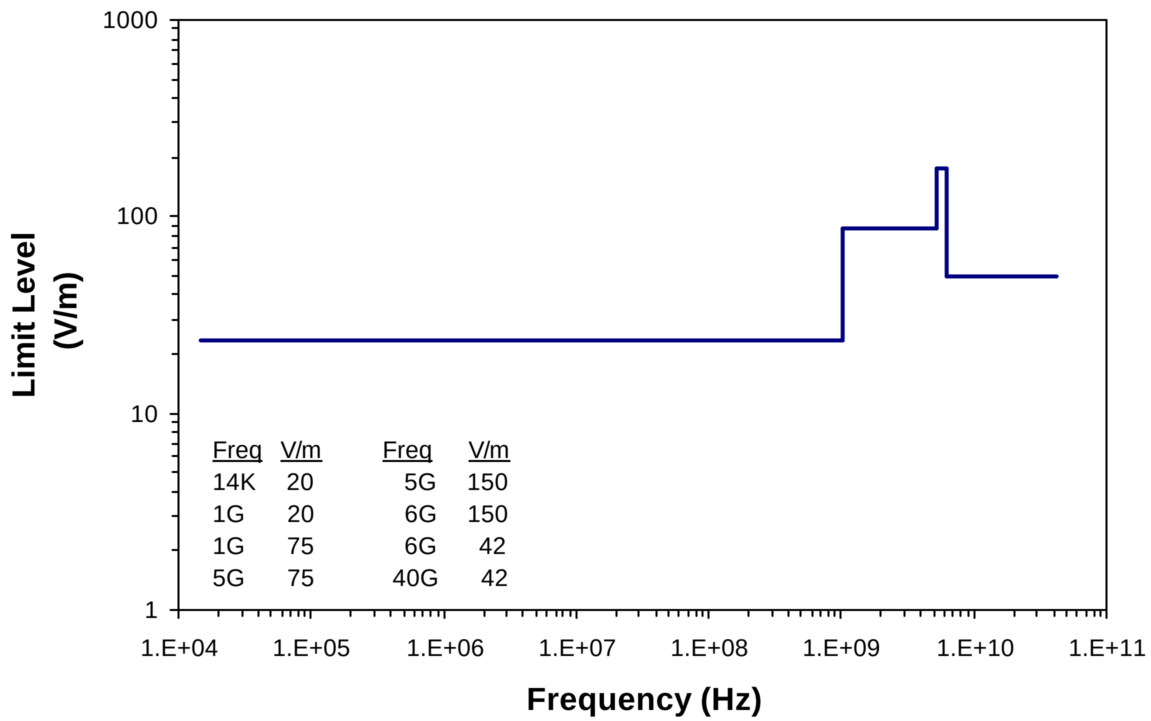


Figure 18. Instrument Launch Electric Field Radiated Susceptibility Survival Limit (RS103) (TBR)

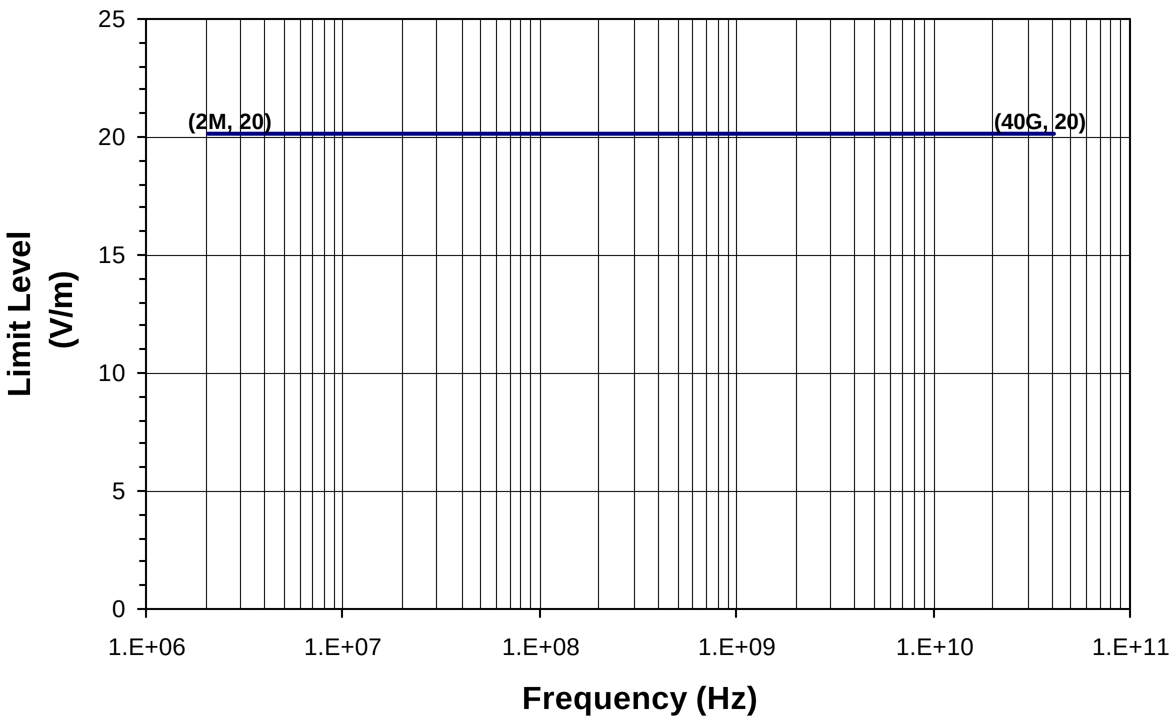


Figure 19. Instrument Perform Electric Field Radiated Susceptibility Performance Limit (RS103)

Table XII. Spacecraft-Generated GLAST RF Sources (TBR)					
Transmitter	**Band**	**Center Frequency (GHz)**	**Modulation Type**	**Bandwidth (MHz)**	**Volts/m @ Inst (E_{peak})**
	USB	2.2875	(TBD)	2.112 (2)	(TBD)
	USB	2.2875	(TBD)	2.112 (2)	(TBD)
	X	7.812	(TBD)	(TBD) (1)	(TBD)
	X	8.212	(TBD)	375 (1)	(TBD)

(1) Width of main lobe of the transmitter spectrum (null to null).

(2) TBD

5.3.2 Radiated Susceptibility, Magnetic Fields (RS101, Static)

The instruments shall perform when subjected to the radiated magnetic field requirement of Figure 20 and the magnetic field requirement of Figure 21. Figure 21 shows the estimate of worst-case magnetic fields at various locations on the Spacecraft produced by the magnetic torque rods.

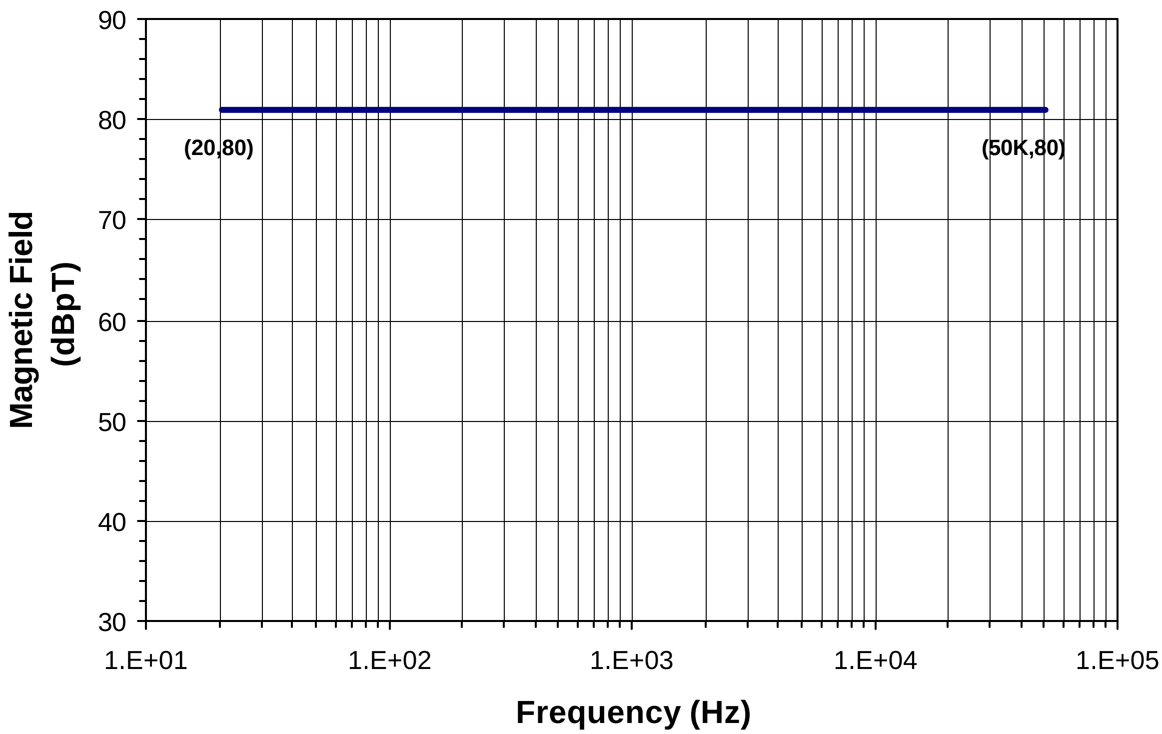


Figure 20. Instrument Magnetic Field Radiated Susceptibility Performance Limit (RS101)

Figure 21. Observatory Torquer Rod Magnetic Fields (TBS)

Figure 22. Not Used

Table XIII. Not Used

5.4 Conducted Susceptibility (CS101, CS116)

[1] Instruments shall perform when subjected to conducted sinewave and pulse modulated (CS101) noise injected on the primary power input per Figure 23. Alternative means of meeting this requirement are detailed in the EMI Test Requirements, Spacecraft Contractor.

[2] Instruments shall operate when subjected in the powered state to both positive and negative polarity transients (CS116-Operate) injected on the primary power input (line-to-line) as shown in Figures 24a & b. Instruments shall operate after being subjected in the unpowered state to both positive and negative polarity transients (CS116-Operate) injected on the primary power input (line-to-line) as shown in Figures 24a & b.

[3] Instruments shall survive when subjected to both positive and negative polarity fuse blow/fault transients injected on the primary power input leads (28 V line-to-chassis and return-to-chassis) as shown in Figure 25 (CS116-Survive). This requirement applies with the unit operating (powered) and nonoperating (unpowered). Testing, to verify compliance, shall be restricted to nonflight hardware.

[4] Instruments shall perform when subjected to transient noise (CS116-Perform) injected on the primary power input as shown in Figures 26a & b.

5.5 Not Used

5.6 Not Used

5.7 Instrument Magnetic Properties

Each instrument stand-alone component static dipole moment shall not exceed 0.3 Am^2 initially and shall not exceed 0.3 Am^2 after torque rod activity.

5.8 Electromagnetic Interference Safety Margin

The Electromagnetic Interference Safety Margin (EMISM) for safety critical circuits (such as EEDs) shall be 20 dB, verified by analysis or test. EMISM for other EMC elements shall be 6 dB, verified by comparison of emissions and susceptibility test data.

5.9 Superposition

The radiated and conducted susceptibility requirements will be superimposed on the system critical circuit under investigation to establish the EMISM. This requirement shall be verified by analysis of equipment EMI test data.

5.10 Bonding

The instrument bonding requirements are as follows:

[1] All metal components and electrical equipment shall be bonded to the Structure Grounding System.

[2] The instrument's equipment and system electrical ground shall be bonded together so that each metal to metal joint is ≤2.5 mΩ DC resistance between elements. Instrument mechanical structures that are not part of the SGS shall be bonded together so that DC resistance is less than 10 Ω between joints.

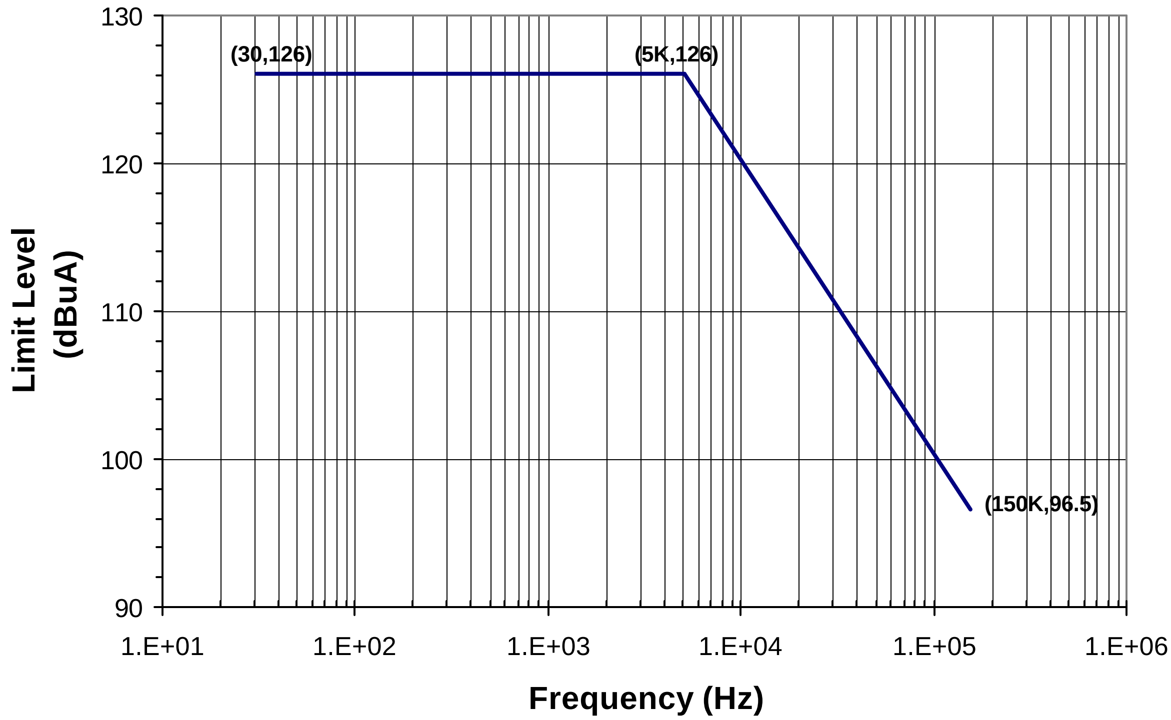


Figure 23. Instrument Conducted Susceptibility Limit (CS101)

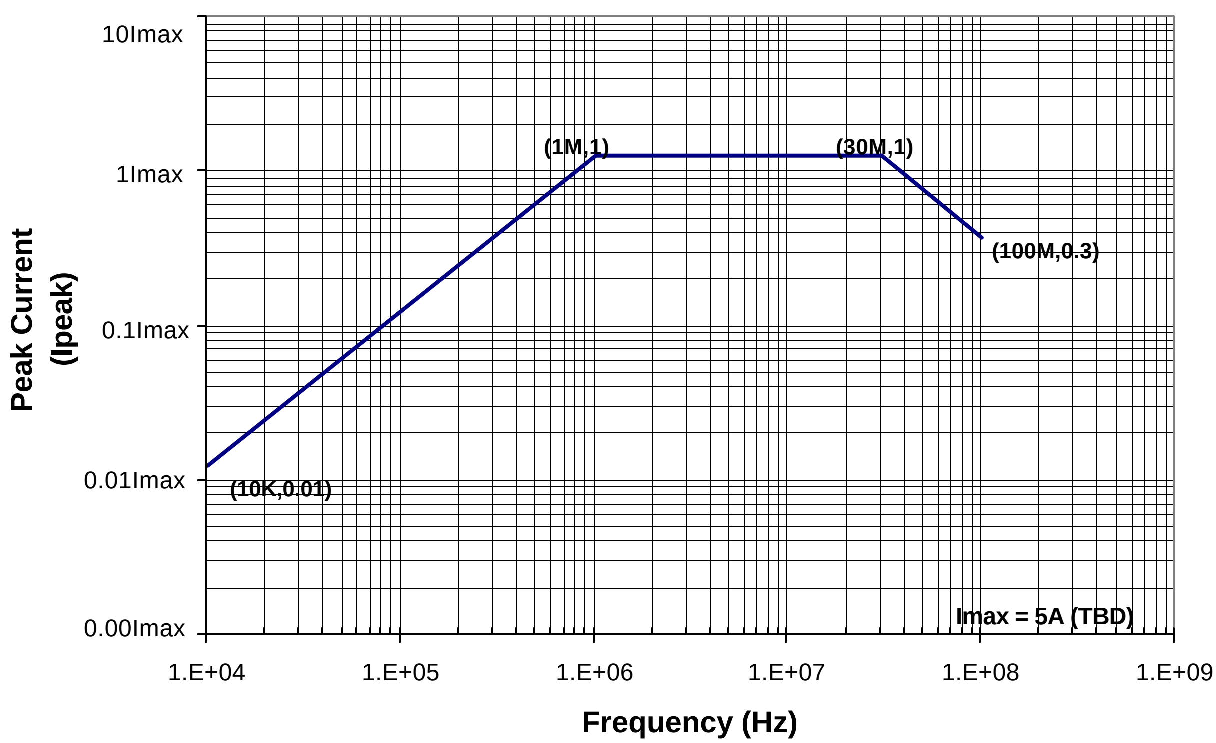
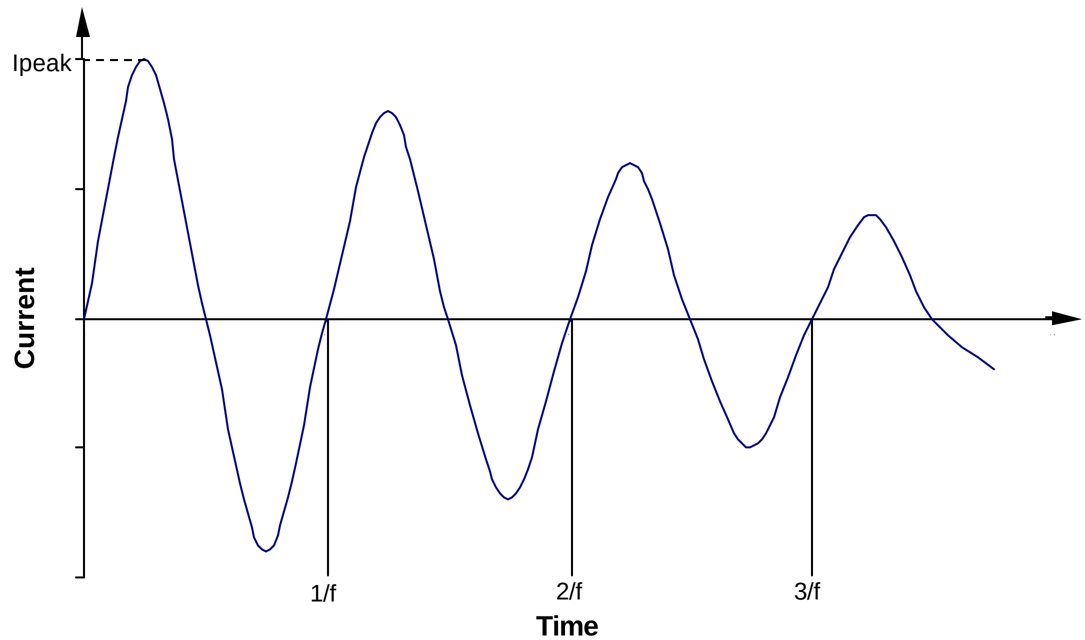


Figure 24a. Instrument Conducted Transient Susceptibility Limit (CS116 -Operate)



NOTES: 1. Normalized waveform: $e^{-(\pi ft)/Q}\sin(2\pi ft)$

Where:
f = Frequency (Hz)
t = Time (sec)
Q = Damping factor, 15 ± 5

2. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N-1)}{\ln(I_P/I_N)}$$

Where:

Q = Damping factor
N = Cycle number (i.e. N = 2, 3, 4, 5, ...)
I_P = Peak current at 1st cycle
I_N = Peak current at cycle closest to 50% decay
ln = Natural log

3. I_P as specified in Figure 24

Figure 24b. Instrument Conducted Susceptibility, Damped Sinusoidal Transient Limit (CS116 -Operate)

Figure 25. Instrument Conducted Fuse Blow/Fault Transient Susceptibility Limit (CS116 - Survive) (TBS)

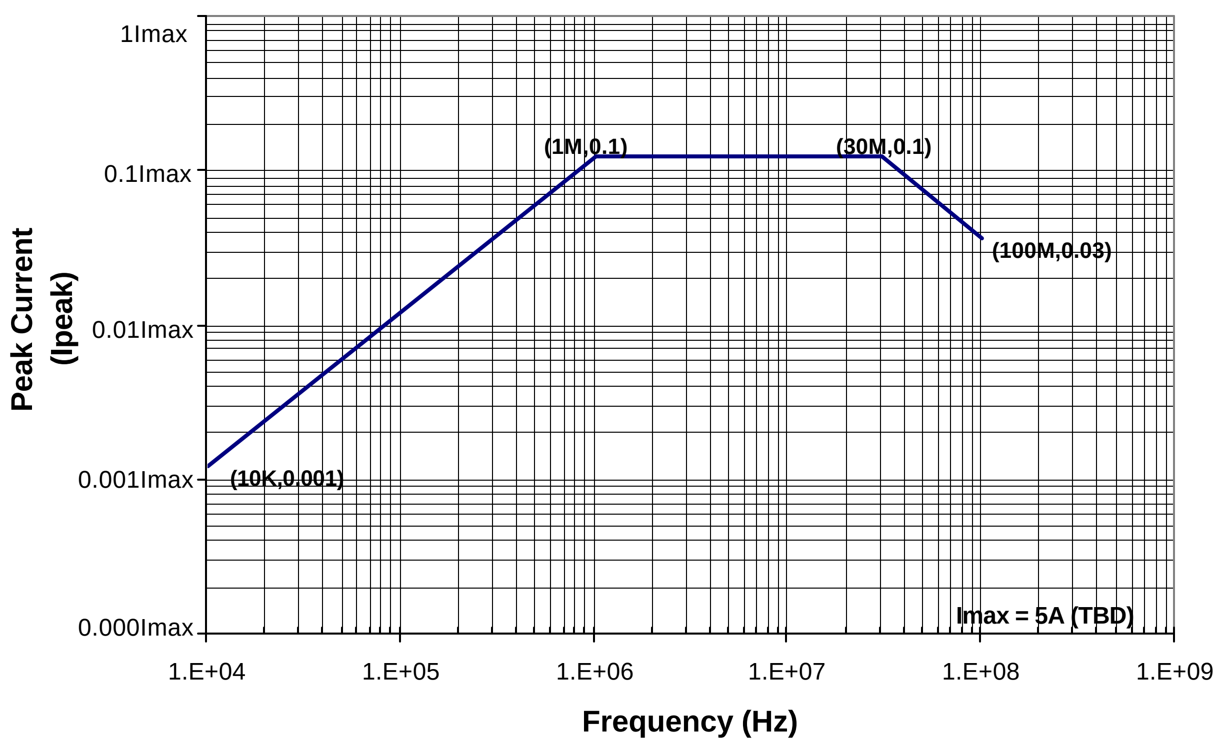
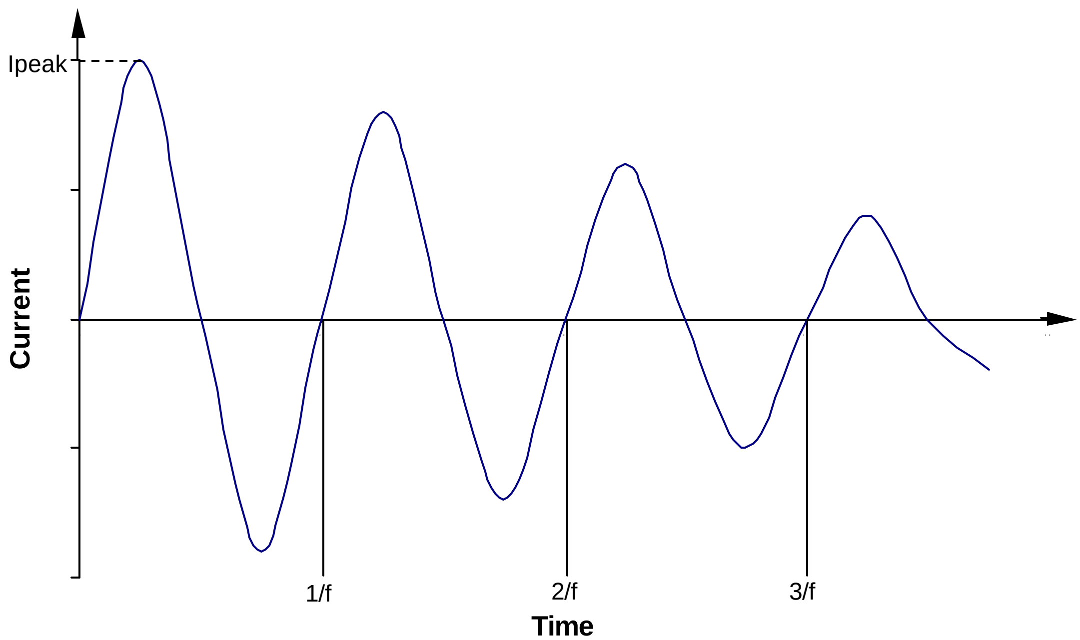


Figure 26a. Instrument Conducted Susceptibility Limit (CS116 – Perform)



NOTES: 1. Normalized waveform: $e^{-(\pi ft)/Q}\sin(2\pi ft)$

Where:
f = Frequency (Hz)
t = Time (sec)
Q = Damping factor, 15 ± 5

3. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N-1)}{\ln(I_P/I_N)}$$

Where:

Q = Damping factor
N = Cycle number (i.e. N = 2, 3, 4, 5, ...)
I_P = Peak current at 1^{st} cycle
I_N = Peak current at cycle closest to 50% decay
ln = Natural log

3. I_P as specified in Figure 26

Figure 26b. Instrument Conducted Susceptibility, Damped Sinusoidal Transient Limit (CS116 -Perform)

[3] Direct bonding is preferred but movable metal to metal joints may use bonding straps providing ≤2.5 mΩ DC resistance and ≤100 nH inductance. Instrument shall be bonded to the SGS with redundant bonding straps, each of which, provide less than 2.5 mΩ and 100 nH bond. The bonding straps shall not restrict Instrument replacement.

[4] Thermal blankets shall be bonded to the structure with less than 1.0 Ω DC resistance and ≤250 nH inductance (measured after installation). Each blanket shall be grounded by a minimum of two grounding tabs. All metalized layers of thermal blankets shall be bonded together with less than 3.0 Ω across all layers when measured close to, but not on, the grounding tabs. The maximum resistance between grounding tabs shall be 3.0 Ω (measured prior to installation).

[5] The bonding surfaces shall use conductive corrosion protection such as alodine for aluminum or DOW 19 for magnesium.

5.10.1 Connector and Shield Bonding

The instrument interface connector and shield bonding requirements are as follows:

[1] Multipin connectors that utilize coaxial or triaxial contacts shall bond the overall shield contact to the interface connectors' shell with ≤ 10 mΩ resistance.

[2] The outer shield of all cables shall be 360 degrees bonded to the interface connector shell.

[3] The outer shield of all coaxial cables shall be bonded to the interfacing equipment case with ≤2.5 mΩ resistance and ≤50 nH inductance.

[4] The outer shield of all twinaxial data bus cables shall be bonded to the interfacing equipment case with ≤2.5 mΩ resistance and ≤50 nH inductance.

[5] The case/outer shield of all equipment which connect to the Spacecraft harnesses shall have the quantity of shielding necessary to maintain the overall shielding performance of the interfacing cables.

[6] The case/outer shield described above shall be bonded to the SGS (directly or via local ground planes) with each bond contributing ≤2.5 mΩ resistance and ≤50 nH inductance.

[7] All connectors shall provide positive bonding mechanisms between mating connector halves and shall have conductive finishes.

[8] Instruments shall bond all data bus cables shields to chassis at the Spacecraft Interface.

[9] All connectors shall be 360 degree bonded to the Instrument case. EMI gaskets shall be used where necessary. Each electrical bond shall be ≤2.5 mΩ resistance.

5.11 Grounding, References, and Isolation

The GLAST Observatory will conform to the system-grounding concept in Figure 27.

5.11.1 Structure Grounding System

[1] Instruments shall not use chassis or the SGS as power return or reference for prime power.

[2] The instrument prime power leads and returns shall be DC isolated from the SGS by at least 1 MΩ.

Figure 27. Observatory Grounding Concept (TBS)

Figure 28. Secondary Electronics Grounding and Data Interface Concepts For All Instruments (TBS)

Figure 29. Not Used (TBD)

Figure 30. Interface Signal Grounding (TBS)

[3] The instruments will be grounded to the Structure Grounding System via the TBD with ≤2.5 mΩ DC resistance.

[4] Each component, and/or instrument chassis shall be bonded to the Structure Grounding System via direct connection, bond strap, or instrument ground interconnection.

5.11.2 Kinematic Mount Isolation

Kinematic mounts used for instrument mounting plates or for direct mounting will provide greater than 10 kΩ DC isolation.

5.11.3 Thermal Blanket Grounding

All metalized layers of thermal blankets shall be grounded to the Structure Grounding System either by direct connection or by bonding to a local chassis or ground plane.

5.11.4 Secondary Power Referencing

[1] Each secondary power return conductor, (except when isolated secondary power is used), shall be grounded to chassis locally thereby providing a DC reference path to the Structure Grounding System. Isolated secondary power is defined, as power that is not used to power "Instrument-to-Spacecraft" interface circuits and power which is totally consumed internally.

[2] Instruments may use an internal single point ground system for isolated secondary circuits such as sensors, and these may be referenced to chassis by any instrument selected real value (i.e., in DC ohms).

[3] Circuits internal to the instruments shall not degrade the system ground and shall limit currents flowing in the instrument chassis.

5.11.5 Signal Interfaces, Grounding, References, and Isolation

[1] The signal grounding between instrument components, Spacecraft system elements, and SGS located equipment will conform to the concept in Figure 28 and Figure 30. All differential interface signals between instrument and Spacecraft electronics shall use a dedicated return conductor (twisted pair) with returns isolated from chassis. The differential interface receiver circuit shall provide 3 kW minimum isolation from chassis ground.

[2] RF signal circuits shall utilize coaxial circuit connections and shall be designed so as to minimize the effect of low frequency currents on the outer conductor.

[3] Except for high-speed digital signals all interface signals with fundamental or rise time frequency components greater than 4 MHz shall require the use of coaxial cable.

[4] High-speed digital signal circuits shall be designed to maximize the use of differential drivers and receivers that provide a return that is isolated from chassis.

[5] High-speed digital signal circuits shall use twinaxial cable unless design constraints require coax or dual coax.

[6] Passive bi-level and passive analog telemetry sensors shall be isolated from chassis by ≥100 kΩ.

5.12 Interface Wiring and Harnessing

[1] The harness between Spacecraft and instruments will comply with the requirements as specified below.

[2] The Spacecraft wiring will be designed in accordance with NASA-STD-8739.3, NASA-STD-8739.4, and Table XIV. The LAT and GBM IRDs shall be used as a reference for definitions of signal types.

5.13 Instrument Ground Support Equipment EMI Requirements

Instrument Ground Support Equipment EMI requirements are as follows.

All Instrument GSE shall be designed to best commercial practices with the following exception:

a. Instrument GSE which is powered during Instrument EMI testing and cannot be located outside the test chamber shall meet the Instrument requirements for RE101, RE102, RS101, and RS103. This requirement is also applicable to all interface cables that connect to the Instrument.

b. Instrument GSE that provides primary electrical power to an Instrument shall not exceed the conducted emissions and/or ripple and noise limits allocated to that Instrument GSE in the applicable performance specification.

Table XIV. Wire Design Requirements (TBR)				
Group Designation	**Spacecraft Signal Type**	**Wire Type**	**Minimum Shielding**	**Shield Termination**
Ia	28 VDC Power	Twisted conductor	OBS	360° @ Backshell
Ib	Secondary Power	Twisted conductor	OBS	360° @ Backshell
IIIa	Analog TLM, Active	Twisted Pair	OBS	360° @ Backshell
IIIb	Analog TLM, Passive	Twisted Pair*	OBS	360° @ Backshell
Ic	Relay Drive Commands	TC (1 Rtn/8 leads with > 2 rtn's /connectors)	OBS	360° @ Backshell
Ic	Logic Level Commands	Twisted Pair	OBS	360° @ Backshell
IIIc	Bi-level TLM, Passive	Twisted Pair*	OBS	360° @ Backshell
IIb	Bi-level TLM, Active	Twisted Pair	OBS	360° @ Backshell
Vc	Time Mark and Freq. Bus	Twinax, similar to Gore CXN2207	2S	360° @ Triaxial Conn.
Vb	Command and TLM Bus	Twinax, Raychem 7724C8664	3S	360° @ Triaxial Conn.
Vb	Science Data (Low Rate)	Twinax, Raychem 7724C8664	3S	360° @ Triaxial Conn.
IIId	Science Data (High Rate)	Dual Gore G2 Coax	2S Foil/Braid	360° @ SMA Conn.
Va	RF/uWave	Coax/waveguide	2S Foil/Braid	360° @ SMA Conn.
IV	EED (Pyro)	1STP	Wrap bundle	360° @ Backshell

Notes:

OBS = Overall bundle shield; **TC** = Twisted conductor **Coax** = Coaxial cable;
Twinax = Controlled impedance twisted shielded pair; **1S** = Single shield; **2S** = Double shield;
3S = Triple shield; **TLM** = Telemetry; * = May be shielded based on location;
Conn. = Connector

The Spacecraft design shall provide wire segregation, routing, shielding and shield termination. A 30 mm separation distance between bundled cables is suggested to reduce mutual coupling between shield currents. The GIID should be used as a reference for definitions of signal types.

Group designations defined in MIL-W-83575A.

6 EQUIPMENT/SUBSYSTEMS EMI REQUIREMENTS

6.1 Equipment Radiated Emissions (RE102, RE101)

[1] Spacecraft equipment, subsystems and components shall not radiate unintentional electric fields in excess of the limits given in Figure 31. Measurement bandwidths above 1 GHz may be modified, if necessary, to achieve sufficient EMI receiver sensitivity.

[2] Spacecraft equipment, subsystems and components shall limit unintentional magnetic field emissions to within the limits specified in Figure 32 measured at 1 meter.

6.2 Equipment Conducted Emissions (CE102, CECM)

[1] Spacecraft equipment, subsystems and components (except the power subsystem) shall limit prime power conducted emissions to levels less than or equal to those shown in Figure 33.

[2] Spacecraft equipment, subsystems and components (except the power subsystem) shall limit prime power common mode conducted emissions to levels less than or equal to those shown in Figure 34, and 100 mV peak-to-peak (TBR) in the time domain.

[3] Repetitive spikes shall meet the conducted emission requirements for CW signals.

6.3 Radiated Susceptibility and Definition of Susceptibility Criteria

The susceptibility criterion for Spacecraft equipment has been divided into three categories. These categories are survive, operate and perform and are defined as follows.

a. Survival is defined as the ability to withstand the applied environment without any permanent loss of performance capability. Survival is required for both powered and unpowered states.

b. Operate is defined as the Spacecraft equipments ability to withstand the applied environment without malfunction, loss of capability, change of operation state/mode, memory changes or need for outside intervention. Operate requires that the survival criteria be met.

c. Perform is the ability of Spacecraft equipment to meet its specified performance. Perform requires that the Operate criteria be met.

The applicability of the above performance criteria versus the applied Environmental levels for Spacecraft equipment is detailed in Table XV.

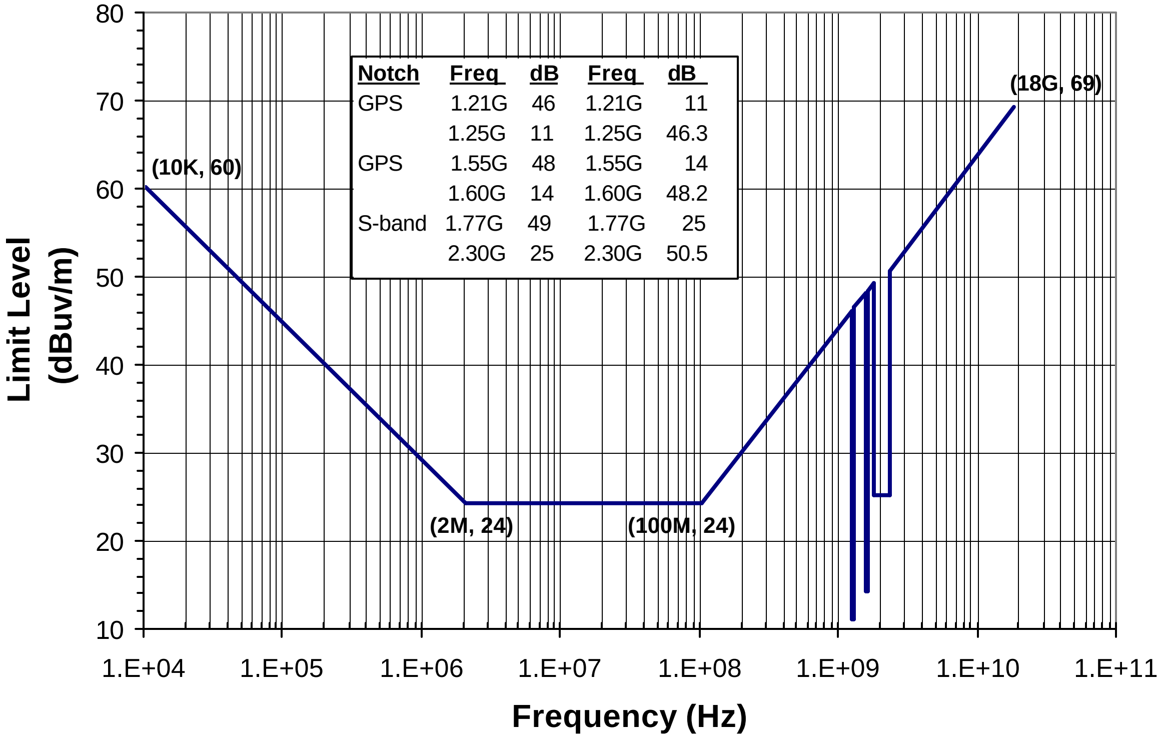


Figure 31. Equipment Radiated Electric Field Emissions Limits (RE102)

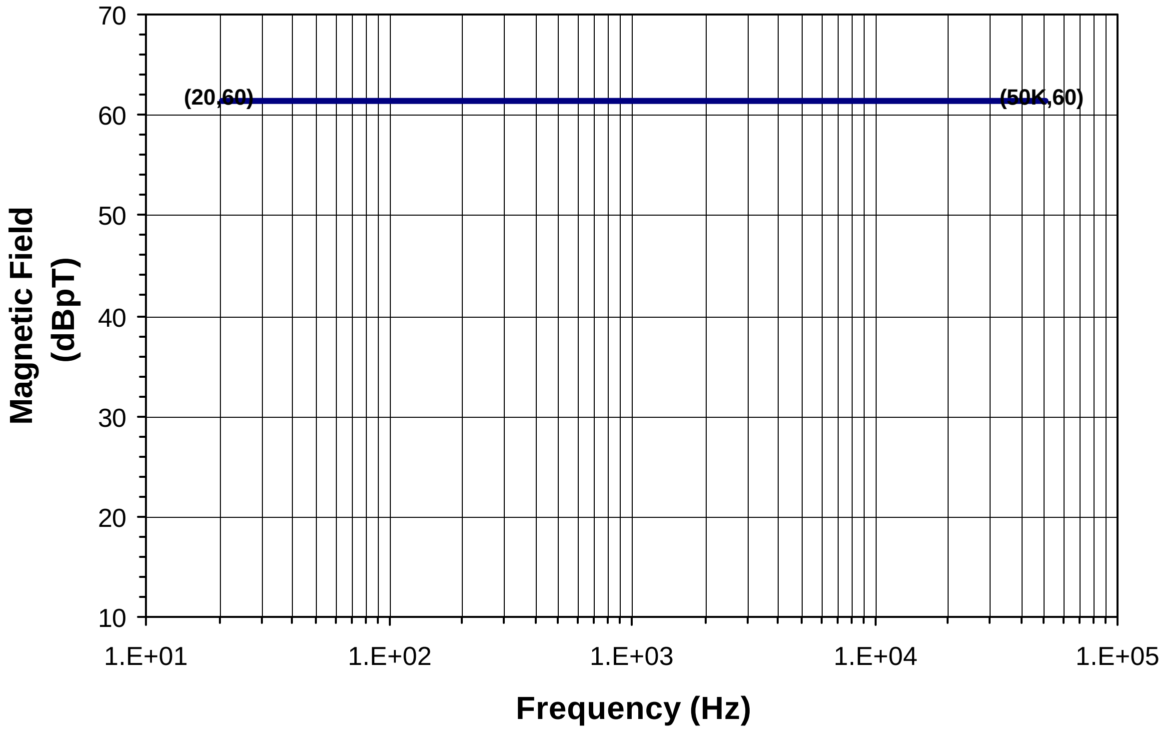


Figure 32. Equipment Radiated Magnetic Field Emissions Limits (RE101)

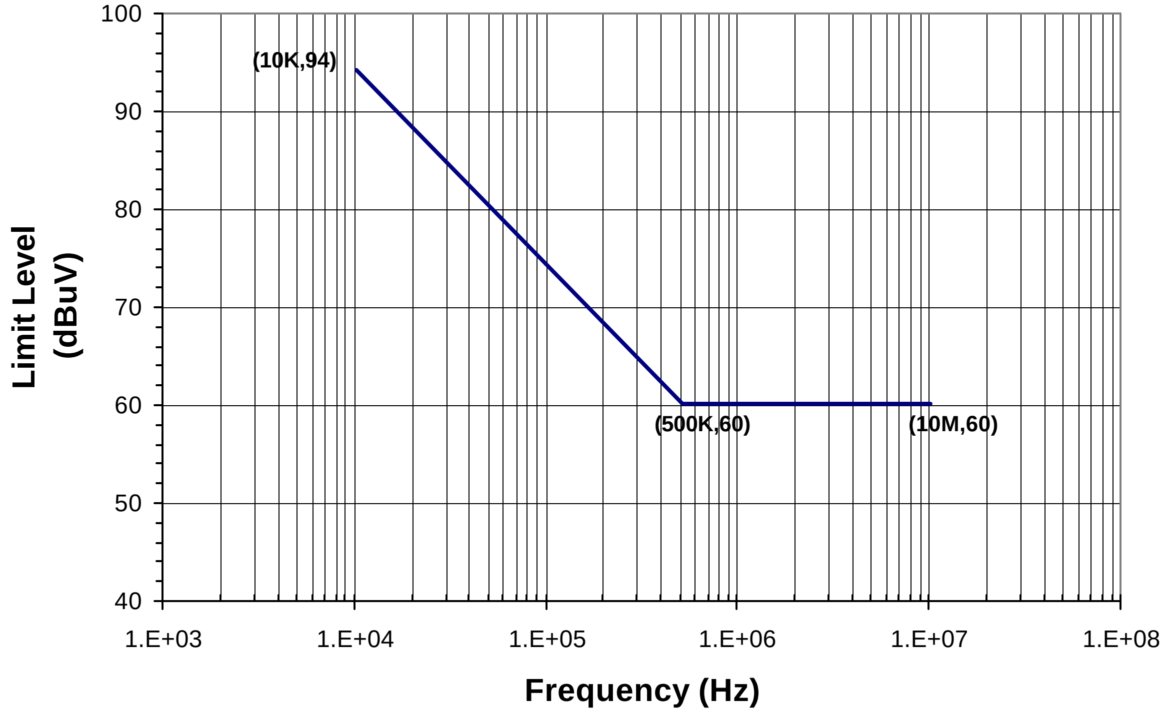


Figure 33. Equipment Conducted Emissions Limits (CE102)

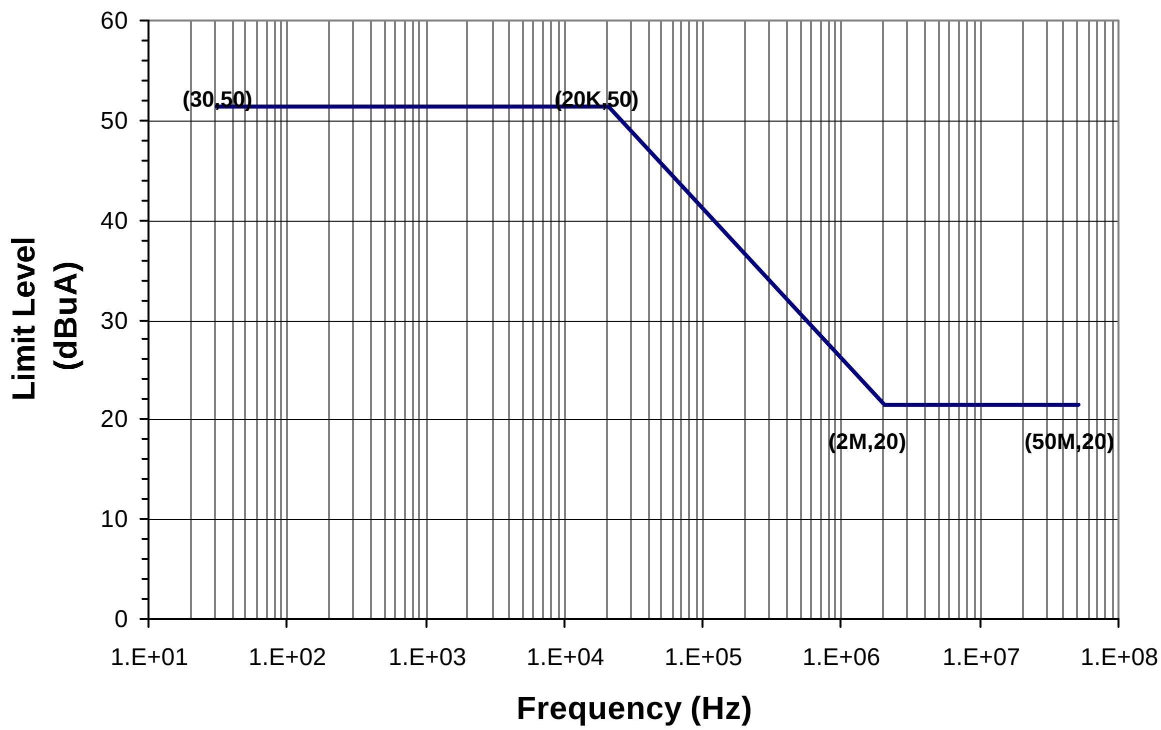


Figure 34. Equipment Common Mode Conducted Emissions Limits (CECM)

Table XV. Equipment Susceptibility Requirements		
	Spacecraft Equipment	
Test	Survive	Perform(5)
CS101	Y	Y
CS116	Y	Y
CS103	Y	Y
CS104	Y	Y
CS105	Y	Y
RS101	Y	Y
RS103(1)	Y(6,4)	Y(6,4)
RS103(2)	Y(4)	Y(4)
Magnetic Properties(7)	Y	Y
Y = Applicable		
(1) Composite of normal checkout, launch vehicle, and launch susceptibility levels (Figure 36) (2) Equipment susceptibility levels (Figure 35) (4) By analysis or test (5) Definition of susceptibility (i.e., criteria for performance defined in test plan) (6) Launch environment reduced by equipment shielding where applicable (7) Immunity to Spacecraft and Earth generated magnetic fields, Box level test		

6.3.1 Equipment Electric Fields Radiated Susceptibility Limit (RS103)

[1] Spacecraft equipment/subsystems and components shall perform when subjected to the susceptibility environments specified in Figure 35.

[2] Spacecraft equipment and core harness necessary for launch shall perform when subjected to electrical fields over the range of frequencies and levels specified in Figure 36. Figure 36 is the applied maximum levels of the ESMC launch environment and the launch vehicle generated environment.

6.3.2 Radiated Susceptibility, Magnetic Fields (RS101, Static)

[1] The Spacecraft equipment, subsystems and components shall perform when subjected to the AC magnetic fields specified in Figure 37 and the Spacecraft magnetic field requirement of Figure 38.

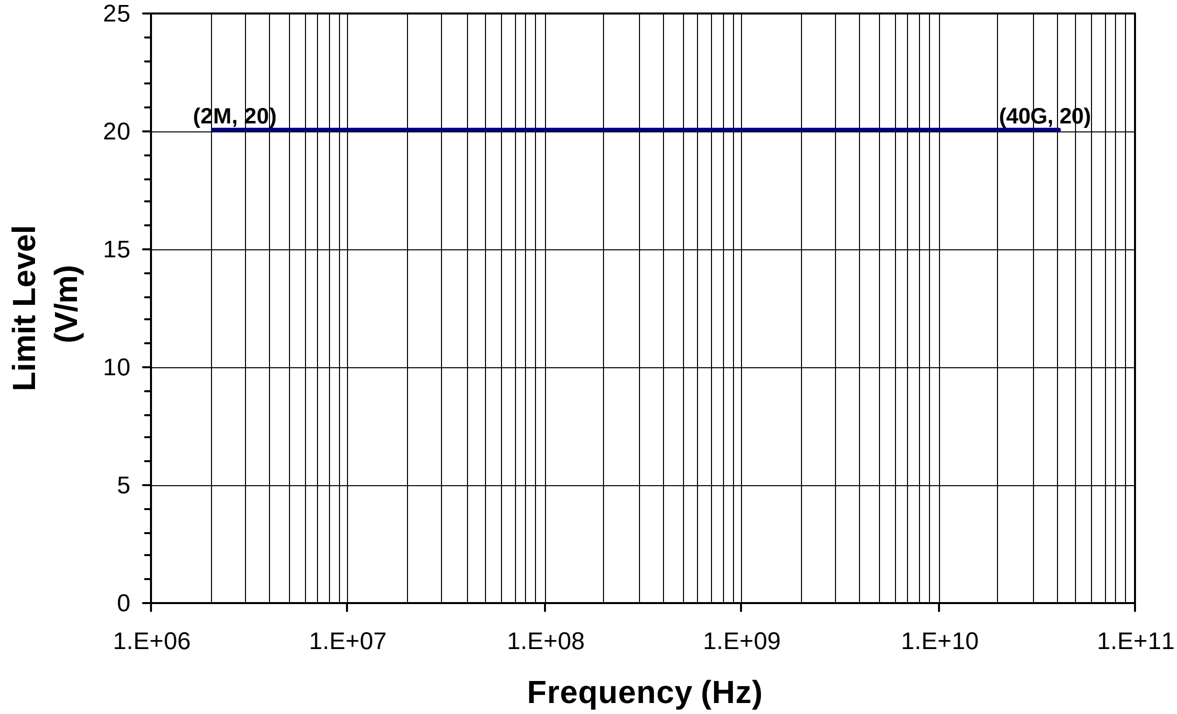


Figure 35. Equipment Radiated Susceptibility, Electric Field (RS103)

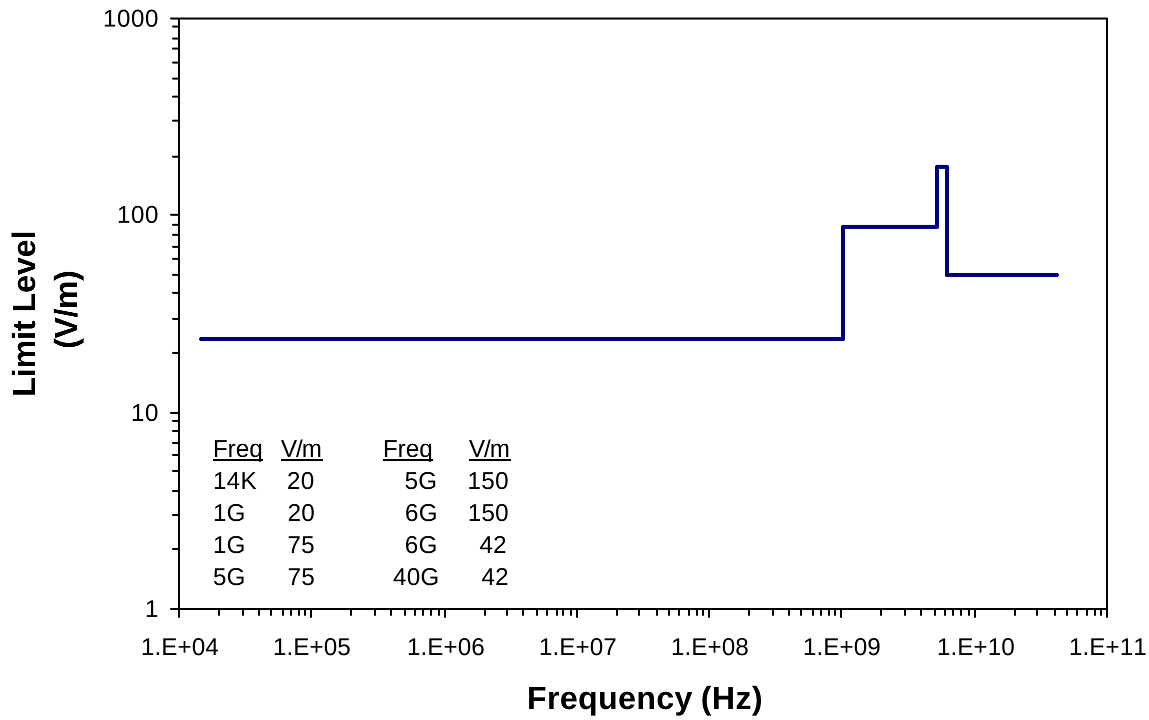


Figure 36. Launch Radiated Susceptibility, Electric Field (RS103) (TBR)

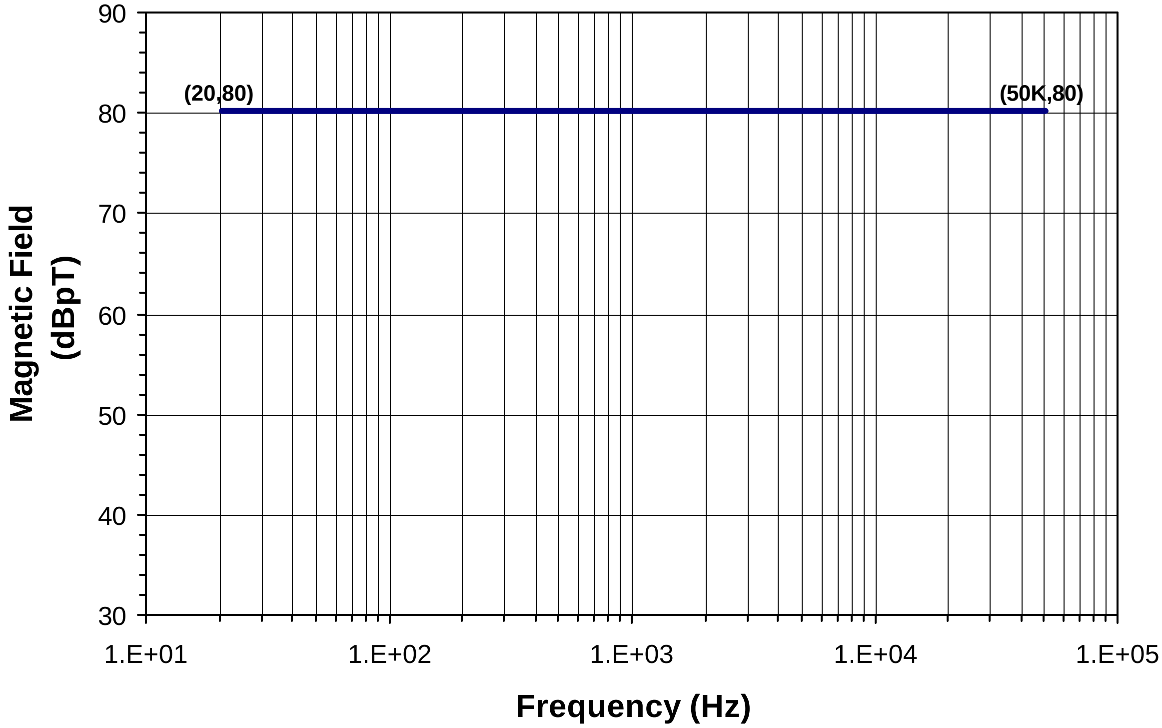


Figure 37. Equipment Radiated Susceptibility, Magnetic Field (RS101)

Figure 38. Spacecraft Torquer Rod Magnetic Fields (TBS)

[2] The Spacecraft equipment critical and necessary for launch shall perform during exposure to a 1.5 Gauss (150 uT) Static Magnetic field. Figure 38 shows the estimate of worst case magnetic fields at various locations on the Spacecraft produced by the magnetic torque rods.

[3] All Spacecraft equipment shall operate in the magnetic field levels shown at the various locations in Figure 38. The magnetic fields will be updated, as more information becomes available and will be incorporated into this document via a Configuration Change Request (CCR).

6.3.3 Communication Equipment Susceptibility Requirements/Definition of Susceptibility

The Spacecraft Communication Equipment shall meet the requirements of paragraph 6.3.1 except where radiated energy is induced directly in the operating band of the equipment. Under these conditions the equipment shall operate when the environment of Figure 35 is applied. Additionally, no damage or permanent loss performance shall result from the susceptibility environment of Figure 36.

6.4 Conducted Susceptibility (CS101, CS116)

[1] Prime powered Spacecraft components, equipment and subsystems shall perform when subjected to conducted sinewave and pulse noise (CS101) injected on the primary power bus input per Figure 39. Alternative means of meeting this requirement are detailed in the EMI Test Requirements, (TBS - Spacecraft Contractor).

[2] Prime powered Spacecraft components, equipment, and subsystems shall perform when subjected to both positive and negative transients (CS116) injected on the primary power bus (line-to-line) per Figures 40a & b.

[3] Prime powered Spacecraft components, equipment, and subsystems shall survive when subjected to positive polarity fuse blow/fault transients injected on the primary power input leads (line-to-line, +28 V line-to-line chassis, and return-to-chassis) as shown in Figure 41. This requirement applies with the unit operating (powered) and nonoperating (unpowered). Testing to this requirement, to verify compliance, shall be restricted to nonflight hardware.

[4] Prime powered Spacecraft components, equipment and subsystems that must operate through all safe modes shall operate when subjected to transient noise (fuse blow/fault transient, CS116 - Survive) injected on the primary power bus per Figure 41 and paragraph [3], above.

[5] Equipment powered from secondary voltages less than 22 volts shall perform when sinewave and transient noise scaled to the ratio of secondary voltage divided by the primary voltage is applied to their power input.

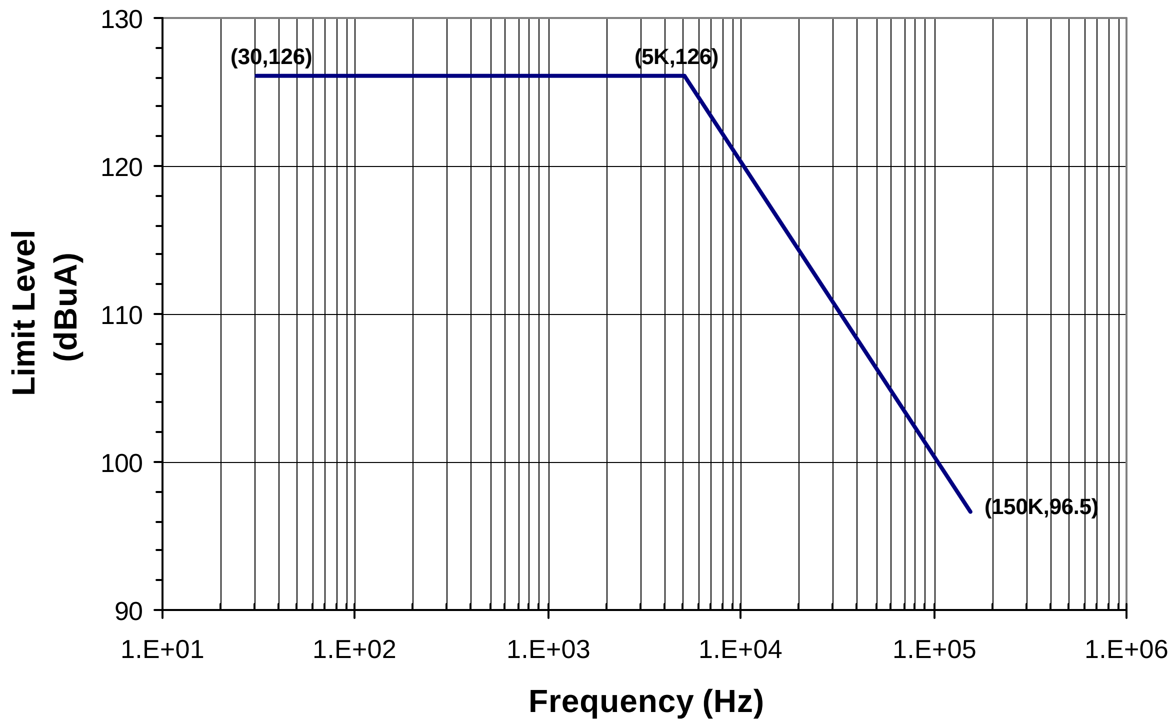


Figure 39. Equipment Conducted Susceptibility (CS101)

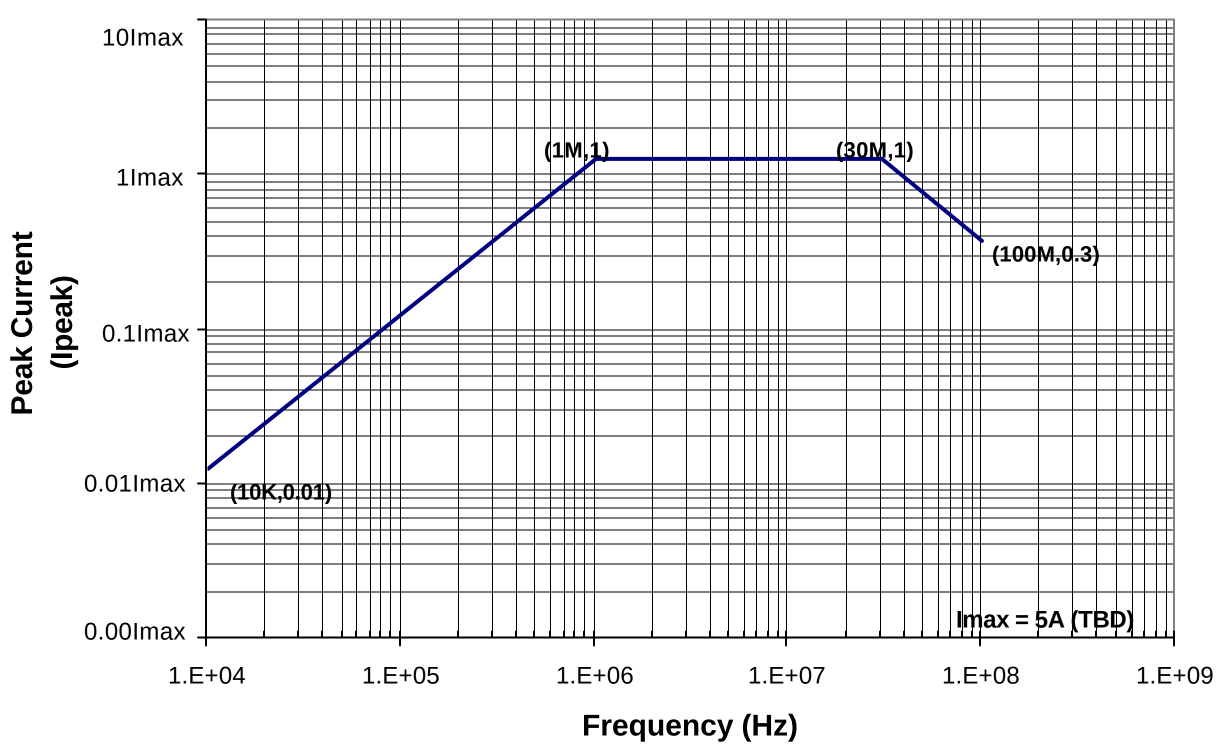
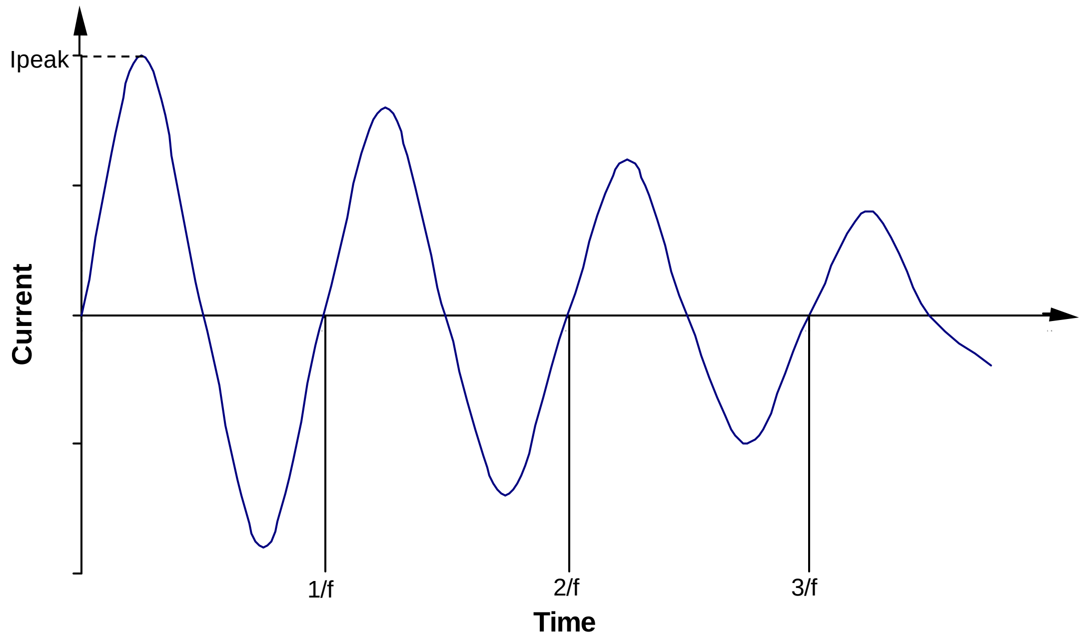


Figure 40a. Equipment Conducted Transient Susceptibility (CS116 – Operate)



NOTES:

1. Normalized waveform: $e^{-(\pi ft)/Q}\sin(2\pi ft)$

   Where:
   f = Frequency (Hz)
   t = Time (sec)
   Q = Damping factor, 15 ± 5

2. Damping factor (Q) shall be determined as follows:

   $$Q = \frac{\pi(N-1)}{\ln(I_P/I_N)}$$

   Where:

   Q = Damping factor
   N = Cycle number (i.e. N = 2, 3, 4, 5, ...)
   I_P = Peak current at 1st cycle
   I_N = Peak current at cycle closest to 50% decay
   ln = Natural log

3. I_P as specified in Figure 40

Figure 40b. Equipment Conducted Susceptibility, Damped Sinusoidal Transient Limit (CS116 - Operate)

Figure 41. Equipment Conducted Fuse Blow/Fault Transient Susceptibility Limit (CS116 – Survive) (TBS)

6.5 Deployment EED/NEA Design

The Spacecraft design shall provide protection from premature deployment of electro-explosive devices (EEDs) and non-explosive actuators (NEAs) in accordance with MIL-STD-1576A.

6.6 Equipment Magnetic Properties

Spacecraft equipment, except torque rods, static dipole moment shall not exceed 0.3 Am^2 initially and shall not exceed 0.3 Am^2 after torque rod activity. Torque Rods shall be designed to limit residual static dipole moment to 5 Am^2.

6.7 Electromagnetic Interference Safety Margin

The Electromagnetic Interference Safety Margin (EMISM) for safety critical circuits (such as EEDs) shall be 20 dB, verified by analysis or test. EMISM for other EMC elements shall be 6 dB, verified by comparison of emissions and susceptibility test data.

6.8 Superposition

The radiated and conducted susceptibility requirements will be superimposed on the system critical circuit under investigation to establish the EMISM. This requirement shall be verified by analysis of equipment EMI test data.

6.9 Equipment Bonding

The Spacecraft equipment shall conform to the requirements as specified in paragraph 4.10.

6.9.1 Connector and Shield Bonding

The Spacecraft equipment shall conform to the requirements as specified in paragraph 4.10.1.

6.10 Equipment Grounding, References, and Isolation

The Spacecraft equipment shall conform to the requirements as specified in paragraph 4.11.

6.11 Equipment Interface Wiring and Harnessing

[1] The Spacecraft harness shall comply with the requirements in Sections 4.10, 4.11, and 4.12.

6.12 Antenna Port Conducted Emissions (CE106)

[1] The Spacecraft receiver and transmitter subsystems shall limit antenna port conducted emissions to the levels specified below. The emissions limits apply at the coax or waveguide port that connects to each antenna after subsystem components such as diplexers, isolators, or couplers and includes signal transmission line sections.

[2] For equipment using waveguide, the requirement shall not apply below eight-tenths of the waveguide's cutoff frequency.

[3] The Spacecraft S-band receiver and transmitter subsystems shall limit antenna port conducted emissions to the levels specified in Figure 42.

[4] The Spacecraft X-band (TBD) receiver and transmitter subsystems shall limit antenna port conducted emissions to the levels specified in Figure 43.

[5] The Spacecraft X-band (TBD) transmitter subsystem shall limit antenna port conducted emissions to the levels specified in Figure 44.

6.13 Receiver Antenna Port Conducted Susceptibility Requirements (CS103, CS104, CS105)

[1] The Spacecraft S-band subsystem/equipment shall not respond to or exhibit degraded performance by intermodulation, rejection of undesired signals, or cross-modulation when subjected to the CS103, CS104 and CS105 methods in MIL-STD-461E.

[2] The Spacecraft X-band subsystem/equipment shall not respond to or exhibit degraded performance by intermodulation, rejection of undesired signals, or cross-modulation when subjected to the CS103, CS104 and CS105 methods in MIL-STD-461E.

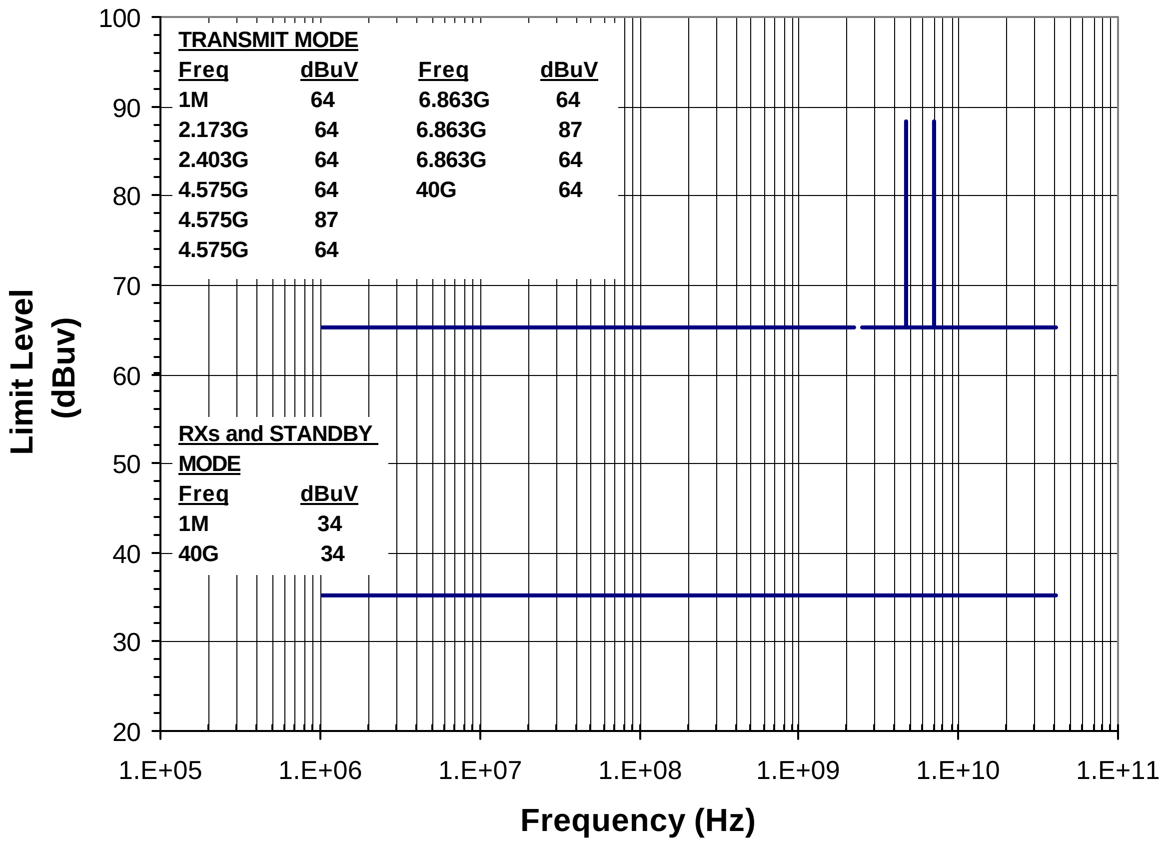


Figure 42. S-Band Antenna Port Emissions (CE106) (TBS)

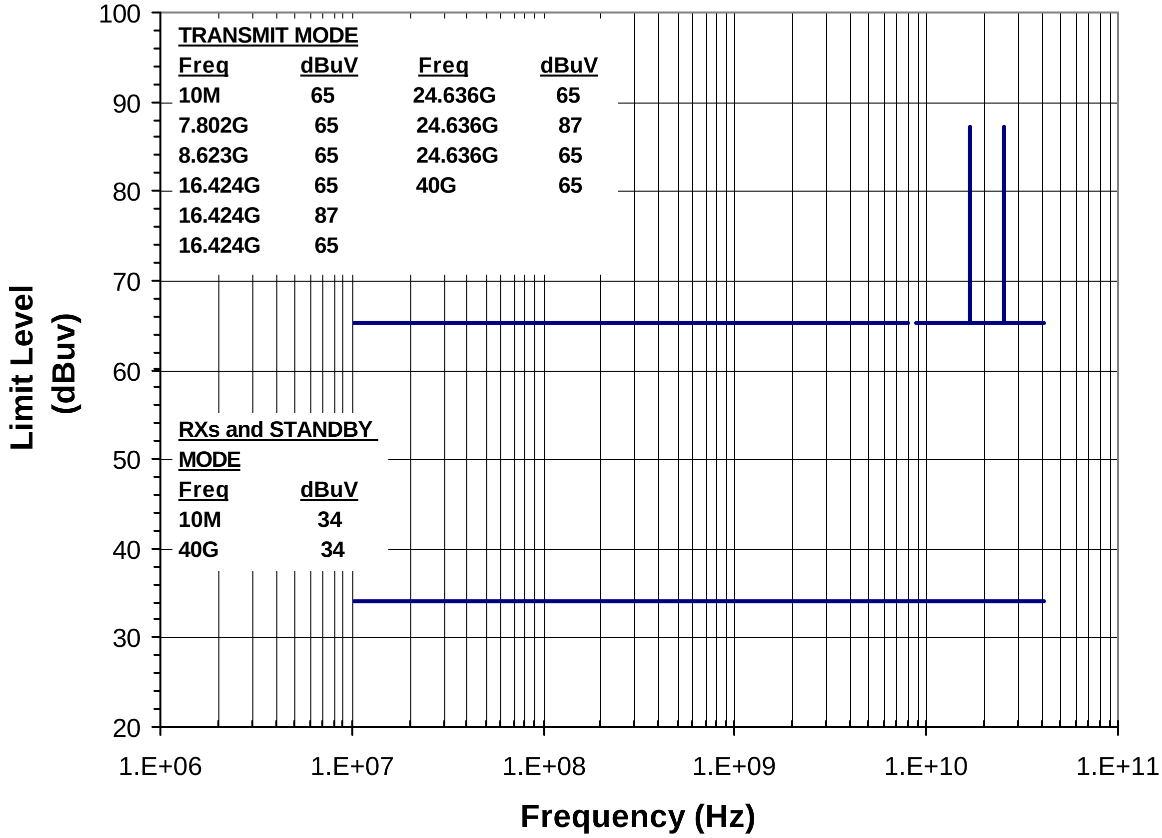


Figure 43. X-Band Antenna Port Emissions: 8.212 GHz (CE106) (TBS)

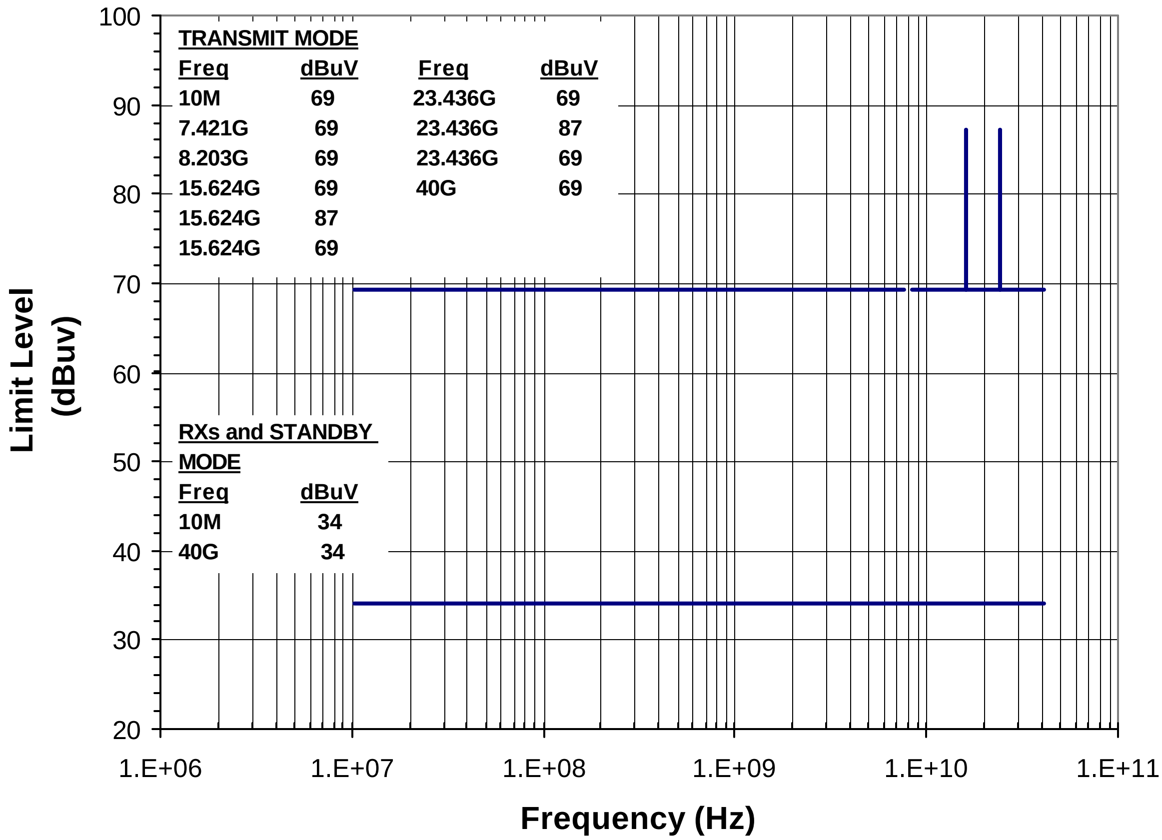


Figure 44. X-Band Antenna Port Emissions: 7.812 GHz (CE106) (TBS)

7 ELECTRICAL GROUND SUPPORT EQUIPMENT (EGSE)

Electrical Ground Support Equipment EMI requirements are as follows.

All EGSE shall be designed to best commercial practices with the following exceptions:

a. EGSE which is powered during Observatory EMI testing and cannot be located at least 60 feet away shall meet the Observatory requirements for RE101, RE102, RS101, and RS103. This requirement is also applicable to all interface cables that connect to the Observatory.

b. EGSE physically located on the Mobile Service Tower shall be designed to meet the requirements of MIL-STD-461E with the following relaxation: LCD and CRT type displays shall not be permanently degraded by the application of RS102 test signals and shall resume normal operation after removal of applied test signals.

c. EGSE that provides primary electrical power to flight hardware shall not exceed the conducted emissions and/or ripple and noise limits defined in the Observatory EMI Requirements Document, 433-RQMT-0005, and specified for the EGSE in the applicable requirements documents.

8 EMI/EMC CONTROL

8.1 Electromagnetic Compatibility Advisory Board

The GLAST Project Office will establish an Electromagnetic Compatibility Advisory Board (EMCAB). The EMCAB is a formal assembly of the Goddard Space Flight Center (GSFC) GLAST Project Office, the spacecraft contractor, instrument providers, and, when necessary, the subcontractors and vendors.

8.1.1 Purpose

The EMCAB shall ensure that the EMI requirements, as put forth in this document, are carried out in the design implementation and assist in achieving electromagnetic compatibility among similar or dissimilar systems, subsystems, and equipment.

8.1.2 Responsibilities

The EMCAB shall be responsible, as a minimum, for the following:

[1] Perform technical evaluations of the EMI/EMC Program status and concerns,

[2] Determine possible solutions and recommend the most suitable corrective action to the proper management,

[3] Review the effects of the recommended action,

[4] Continue reviewing and updating the EMI/EMC Program,

[5] Ensure communications between EMCAB members and their organizations,

[6] Review and recommend disposition of EMI/EMC documents including Control Plans, Test Plans, Test Reports and Analysis Reports,

[7] Evaluate and recommend disposition of Engineering Review Board (ERB) and Change Control Board (CCB) waiver and deviation requests,

[8] Implement processing of the recommended actions by the proper management,

[9] Coordinate EMI/EMC issues/activities with all other areas of the Project, and

[10] Generate EMCAB-related schedules and update as necessary.

8.1.3 EMCAB Chair

The GLAST Project Office will appoint a GSFC Representative to chair the Board with participation by the organizations stated in section 8.1.

9 DEFINITIONS AND COMMONLY USED TERMS

9.1 Glossary

The following terms are defined to facilitate specification of the ground, return, reference and bonding requirements:

Bond:	A low-impedance electrical connection between two conductive elements
CE101:	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102:	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106:	Conducted Emissions, Antenna Terminals 10 kHz to 40 GHz
CECM:	Conducted Emissions, Common Mode, 30 Hz to 50 MHz
Chassis Reference:	The point within a component at which signal reference and secondary power return leads are referenced to the component chassis
Component:	A generic term used to describe independently packaged electronics
Chassis:	The metal enclosure that shields electronic circuits.
CS101:	Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz
CS103:	Conducted Susceptibility Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104:	Conducted Susceptibility Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105:	Conducted Susceptibility Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS116:	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10kHz to 100 MHz
Equipment:	A generic term used to describe independently packaged components and subsystems. A group of components that work together and whose operation is interrelated are also categorized as equipment.
Equipment Chassis:	The metal enclosure that shields the Equipment's electronics.
Ground Plane:	The local electrically conductive surface to which a component is bonded
Instrument Chassis:	The metal enclosure that shields the instrument's electronics

Instrument Ground Connection:	The electrically conductive surface or virtual ground point to which all instrument components and its accommodation equipment are bonded.
Intentional Emissions:	The signal or spectrum of emitted energy that is the fundamental purpose of operation. Example: The RF output of a transmitter is an intentional emission at the transmitting antenna, while leakage of the transmitter output from the case of the transmitter is an Unintentional Emission. See Unintentional Emission.
Isolated Secondary Power:	A secondary power source whose loads are completely isolated from instrument to Spacecraft interface electronics
Primary Power Reference:	The point on the Spacecraft where all primary power returns are referenced. The Primary Power Reference is the reference point for Spacecraft voltage control.
Primary Power Return:	The isolated 28 V current return lead from the component primary power dc-to-dc converter input back to the Spacecraft primary power distribution point
RE101:	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102:	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RF Signals:	RF Signals are those that require coaxial cable and connections. RF Signals typically have fundamental components above 4 MHz.
RS101:	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103:	Radiated Susceptibility, Electric Field, 10 kHz to 18 GHz
Secondary Power:	Power that has been derived and isolated from primary power typically by a dc-to-dc converter, and used to power Spacecraft interface or other circuits
Secondary Power Reference:	The point within the component where all current returns from the secondary power circuits are referenced
Signal Reference:	The reference within the component for digital and analog signals.
Structure Grounding System:	The Spacecraft conducting plate or other structure to which all ground planes are connected
Signal Return:	The wire that carries the current of a digital or analog signal back to its source

Unintentional Emissions:	The signal or spectrum of emitted energy that is a by-product of operation. Internally generated signals that are necessary for operation of a device but are not the specified and desired output are Unintentional Emissions. See Intentional Emissions.

9.2 Acronyms and Abbreviations

A	Ampere
AC	Alternating Current
CCB	Change Control Board
CCR	Configuration Change Request
CDRL	Contract Data Requirements List
CE	Conducted Emission
CM	Common Mode
CRT	Cathode Ray Tube
CS	Conducted Susceptibility
CW	Continuous Wave
dB	Decibel
DB	Direct Broadcast
DC	Direct Current
EED	Electro Explosive Device
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMCAB	Electromagnetic Compatibility Advisory Board
EMI	Electromagnetic Interference
EMIRD	EMI Requirements Document
EMISM	Electromagnetic Interference Safety Margin
ERB	Engineering Review Board
ESMC	Eastern Space and Missile Center
EWR	Eastern and Western Range
G	Giga (10^9)
GBM	GLAST Burst Monitor
GEVS	General Environmental Verification Specification
GN	Ground Network
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
H	Henry
HRD	High Rate Data
Hz	Hertz (sec^{-1})
IRD	Interface Requirements Document
JSC	Joint Spectrum Center
JSC*	Johnson Space Center

k	Kilo (10^3)
LAT	Large Area Telescope
LCD	Liquid Crystal Display
MAR	Mission Assurance Requirements
M	Meg (10^6)
m	milli (10^{-3}) or meter
n	Nano (10^{-9})
NEA	Non-Explosive Actuator
p	Pico (10^{-12})
PPR	Primary Power Reference
RE	Radiated Emission
RF	Radio Frequency
RS	Radiated Susceptibility
SE	Space Transportation System & Expendable Launch Vehicle
SGS	Structure Grounding System
SN	Space Network
SPG	Single Point Ground
SRD	Science Requirements Document
SSA	S-band Single Access
T	Tesla
TLM	Telemetry
u	Micro (10^{-6})
V	Volt
W	Watt
Ω	Ohm